

Growing Healthy Crops and Healthy Profits

December 6-8, 2005
Grand Rapids, Michigan



Onion

Wednesday morning 9:00 am

Moderator: Amy Irish-Brown, MSU Extension Fruit & Vegetable

9:00 a.m. Weed Control in Onions

Bernard Zandstra, Horticulture Dept., MSU

9:15 a.m. Symptoms, Damage and Management of Nematodes on Onions in New York

George S. Abawi, Plant Pathology (Geneva), Cornell Univ.

9:35 a.m. Cover Crops and Rotational Strategies in New York

John Mishanec, Integrated Pest Management Program, Cornell Univ.

10:00 a.m. Brassica Biofumigants for Onion Production

Mathieu Ngouajio, Horticulture Dept., MSU
Guangyao Wang, Michigan State University

10:20 a.m. Insect Management in Onion

Edward Grafius, Entomology Dept., MSU

10:40 a.m. Iris Yellow Spot Virus of Onion

Lindsey du Toit, Washington State

Weed Control in Onion – 2006

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Changes in Onion Weed Control – 2005

- Outlook - full federal label - 1 application of 0.98 lb ai (21 fl oz) after 2 LS.
- Chateau labeled for onion - 1-2 applications of 0.032-0.064 lb ai (1-2 oz) during 3-6 LS.
- Prowl H₂O labeled for onion.
- Goaltender labeled for onion.

Chateau is now labeled for onion

- Chateau - flumioxazin - Valent Corp.
- Formulation - 51 WDG
- label: max. of 2 oz (0.064 lb)/application and 3 oz/acre/year
 - apply to onion 3-6 leaf stage
 - tank mixing with other chemicals and adjuvants may cause crop injury
 - 45 day PHI

Weeds Controlled PRE by Chateau

- | | |
|------------------------|--------------------|
| • Common chickweed | • prostrate spurge |
| • common lambsquarters | • smartweeds |
| • nightshade | • barnyardgrass |
| • pigweeds | • crabgrass |
| • mustards | • groundsel |

Concerns with Chateau in Onion

- Crop injury - Chateau has pre and post activity: When is it safe to use?
- Tank mixes – potential crop injury if applied with adjuvants or other herbicides
- Timing – When is the most effective application period?
- Weed control – Does it add anything to currently labeled products?

Conclusions from Onion Weed Control Research – 2005 (1)

- Tank mixes of Chateau with other pesticides with petroleum solvent formulations may increase crop injury.
- Adjuvants with Chateau may increase onion injury.
- Separating Chateau application from other pesticides by 1 week will reduce chance of injury.

Conclusions from Onion Weed Control Research – 2005 (2)

- Use of water-based formulations for tank mixes with Chateau reduces potential of onion injury.
- Too many herbicides in tank mixes will cause onion injury.
- Chateau improved control of nightshades, groundsel, lambsquarters, mustards.
- Chateau has minimal effect on nutsedge.

Recommendations for Onion Weed Control – 2006

- Use Prowl 3.3 or generic pendimethalin PRE
- Use Prowl 3.3 POST alone or in tank mixes with Goal up to 4 oz.
- Use Prowl H₂O 3.8 after 2 LS in tank mixes with Goal and a grass killer.
- Use Goaltender 4 SC in 4 product tank mixes, or with NIS.
- Apply Chateau at 1 oz/acre alone after 3 LS.
- For experiment, tank mix 1 oz Chateau with 1-2 oz Goal 4 SC at 3-4 LS.

An Onion Weed Control Plan for 2006 (1)

- April 1-30, Work soil, plant onion and barley.
- Just before onion emergence, apply Prowl 3.3 2.4 qt + Buctril 4 EC 0.3 pt.
- May 20-30, Kill barley at 4"-6" with Fusilade, Poast, or Select + COC.
- June 1-6, Full 2 LS apply Prowl H₂O 1.9 qt or Outlook 21 fl oz + Goal 2 E 2-4 oz or Goaltender 1-2 oz.
- June 10-20, apply Chateau 1 oz to control nightshade, mustards, chickweed, groundsel.

An Onion Weed Control Plan for 2006 (2)

- July 1-10, Apply Prowl H₂O 1.9 qt **or**
- Dual Magnum 1.3 pt + Goaltender 2-3 oz + grass killer.
- July 15-20, Apply Prowl H₂O 1.9 qt or Outlook 21 oz (if not applied earlier) + Goaltender
- July 10-20, Apply Chateau 1 oz alone before or after Prowl / Outlook / Goal / Select.

Remember

- Reduce product amount per acre if using Prowl H₂O, Goaltender, or Buctril 4EC.
- Outlook label allows 21 fl oz / acre / year.
- Chateau label allows 3 oz / acre / year.
- Do not tank mix Chateau until you have experimented with it and know how to use it.
- Dual Magnum requires signing an indemnification form - for use by members of MVC.

Symptoms, Damage, and Management of Nematodes on Onions in New York

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DISTRIBUTION: The results of an extensive statewide survey conducted during the 1998-1999 seasons clearly documented that the northern root-knot nematode (*Meloidogyne hapla*) was the most prevalent nematode infecting onions. It was recovered from 51% and 84% of the fields sampled by direct extraction from soil or by the soil bioassay with lettuce, respectively. The population of the northern root-knot nematode averaged 103 (range 40-720) juveniles/100 cc soil and 18 (range 3-72) eggs/g root. The lesion nematode (primarily, *P. penetrans*) was second in prevalence, having been recovered from 24% and 35% of the fields when extracted from the soil or roots, respectively. The number of lesion nematodes averaged 67 (range 40-160)/100 cc soil and 289 (range 2-2940)/g root. Stubby-root (*Paratrichodorus allius* and *P. minor*), bloat (*Ditylenchus dipsaci*), and stunt (*Tylenchorhynchus* spp.) nematodes were only detected from 3, 1, and 4 fields, respectively. Interestingly, the recovery of northern root-knot and lesion nematodes differed greatly between the different onion production regions in New York.

SYMPTOMS: Above-ground symptoms on onions severely infected by the northern root-knot and lesion nematodes are similar and include stunting, delayed maturity, thicker necks, and smaller size bulbs which results in reduced marketable yield. However, symptoms that are diagnostic of infection by root-knot nematodes are found on infected roots as galls (knots) or root thickenings of various sizes and shapes. In addition, extensive root branching is also found associated with the galls or root thickenings as well as mature females with egg sacs that can be clearly observed with the aid of a hand lens. The presence of root-knot nematode can be further confirmed by extracting eggs from roots or second stage juveniles from soil around roots of infected plants. Infection of onion roots by the lesion nematode does not result in visible symptoms. Thus, it is important to extract the lesion nematode from infected onion roots or from the soil around such roots in order to confirm their involvement.

DAMAGE: The root-knot and lesion nematodes can cause significant yield losses to onions in fields with high soil populations. Onion bulb weight was reduced by up to 70% in sections of commercial fields heavily infested with the root-knot nematode compared to the lightly infested sections in the same fields. In addition, the yield of the cultivars 'Paragon' and 'Norstar' was reduced by 55% and 49%, respectively in experimental plots infested with 20 root-knot nematode eggs per cc soil. In field microplots, damage to onions by the lesion nematode was increased as the soil population of this nematode was increased from 1 to 4 nematodes/cc soil.

MANAGEMENT OPTIONS: The cost-effective management of nematodes requires the application of nematicides or other control options on an as needed basis. Thus, the availability of a simple and economical procedure for assessing the soil infestation levels of the root-knot and lesion nematodes is critical for triggering any needed control options. Traditional assessments involve the direct extraction of nematodes from soil and/or roots and then counting the recovered nematodes under a microscope. Not only is this labor intensive, it is also costly with most laboratories charging over \$25.00 per sample. We have demonstrated the effectiveness of two simple and visual soil bioassays for the root-knot and lesion nematodes using lettuce and California blackeye pea indicator plants, respectively. In collaboration with Cornell Extension Educators, we are currently offering training to interested growers and consultants on

conducting these on-farm bioassays. These assessment procedures will be illustrated and discussed during the presentation.

Chemical Control - The use of pre-plant soil fumigation is highly effective in controlling plant-parasitic nematodes, including the root-knot and the lesion nematodes. However, the majority of the fumigant nematicides are no longer available, are costly, and difficult to apply. Although, Telone-C and Vapam are available, they are not widely used in New York. Results of extensive evaluations in New York showed that the soil application of Vydate at planting time was cost-effective in controlling these nematodes when present at high populations. A Special Local Need 24(c) label for Vydate use on onions to control the root-knot nematode was initially approved in 1999 and has been extended to December 31, 2006. We have continued the annual evaluation of promising chemical and biological nematicides in field microplots infested with the root-knot or the lesion nematodes. Among the promising chemical nematicides, both Basamid (granular, 350 lbs./A) and Fosthiazate (EC, 4.8 pts/A) applied two weeks prior to planting have given excellent nematode control, but variable yield responses.

Crop Rotation and Cover Crops - Both the northern root-knot and lesion nematodes have a wide host range which makes it difficult to design crop rotations that effectively suppress the population and damage of both nematodes. Rotating onions with grain crops (corn, wheat, barley, ryegrain, ryegrass, oats, sudangrass) is effective in controlling the northern root-knot nematode. However, good weed control is also required as dandelion, purslane, plantain, mallow and other weeds were found to be hosts to the root-knot nematode. Unfortunately, most grain crops are good hosts to the lesion nematode and only ryegrass appears to have some tolerance (supported the lowest build-up of the nematode population among the grain crop tested). Sudangrass incorporated as a green manure will suppress the population of both nematodes and their damage to onions and other vegetables. We found that decomposition by-products (cyanogenic products including hydrogen cyanide) are the primary factors responsible for nematode suppression. Rapeseed and other cruciferous crops incorporated as green manures also appear promising in controlling these nematodes.

Biological - All of the commercial onion cultivars, promising breeding lines, and a large number of the germplasm accessions evaluated for resistance to root-knot nematode were found to be susceptible. However, there were differences in root-galling severity ratings and nematode reproduction among the varieties, especially in the field tests. All the commercial preparations of available biological control agents evaluated were either not effective or gave inconsistent results. However, promising preliminary results have been obtained with Actigard, BioYield, and STAN (a seed treatment product with activity against nematodes produced by Syngenta).

Selected References:

Widmer, T.L., J.W. Ludwig, and G.S. Abawi. 1999. The northern root-knot nematode on carrots, lettuce, and onions in New York. New York's Food and Life Sci. Bull. No. 156, 2 pp. (ISBN 0362-0069).

Widmer, T.L. and G.S. Abawi. 2000. Mechanism of suppression of the northern root-knot nematode by sudangrass incorporated as a green manure. Plant Disease 84: 562-568.

Schwartz, H.F. and S.K. Mohan. 1995. Compendium of onion and garlic diseases. APS Press, 3340 Pilot Knob Road, St. Paul, Minnesota. 54 pp.

Onion Rotational Strategies

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There are close to 5600 acres of onions grown on organic soil in Orange County, New York. Over the years, many onion growers have expressed an interest in learning ways to increase the fertility of their high organic (muck) soils. In some cases, fields have been in uninterrupted onion production for two or more generations. One idea is using Sorghum/Sudan grass (Sudex) as a summer cover crop. A few growers had tried using Sudex with mixed results.

The goals in carrying out field trials with Sorghum/Sudan grass were to figure out all the basic management considerations and document the positive and negative results. After 6 years of in field trials, here is what we have learned.

1993 Results

- The 40-50 lb. rate that were mowed once were by far the thickest, most lush fields in the trial. By mowing, tillering had occurred. Five to six new shoots had come up from each original plant. The tops remained green and were not woody. By early September, the height of the tops averaged 6 feet. Plants were dug up and the roots weighed. Roots consistently averaged at least five times the weight of the non mowed fields. Root growth on the mowed fields extended down 18-20 inches compared to the 6-8 inch long roots on the fields allowed to grow to maturity.
- The 25 lb. rate was found to be too thinly planted. Weeds were not shaded out in the 25 lb. rate field. The plants were very woody and 12 foot tall. The grower had difficulty in plowing down the woody top growth. He waited till the ground had frozen, disked and then plowed the field in the spring.
- Most fields were planted in early to mid June. We looked at mid July and early August plantings. The mid June fields were the most manageable. You could control problem weeds (nutsedge) and then plant. Also, you got a good jump up with available water. Sudan grass will just sit there if there is no water available. We saw this in the later plantings. Root systems did not fully develop in the July and August plantings compared to the earlier plantings.
- The field that had been mowed had developed multiple stems and surprisingly had much more top mass. The mowing stimulated growth. Root growth was much more substantial and deep in the mowed field. Even with more biomass, diskling, then plowing the shorter, less woody plants was much easier than having to deal with 12 foot tall “trees”.
- If you have poor soils, a shot of 75 lbs. of urea helped the Sudex to get going.
- Realistically, 50 lbs./acre was the actual (and best) planting rate with all farmers using a “cyclone” type planter. A light diskling after planting works the seed in.

1994 trials

- The growers were happy with the early fall management aspects of the Sorghum/Sudan grass. The crop was easily incorporated into the soil.
- 1994 experienced a wet spring. Fields in Sorghum/Sudan grass the previous year had no drainage problems. All three growers expressed the belief that the 1993 test plot fields were their best onions this summer. The deep rooting characteristics of Sorghum/Sudan grass promote increased soil drainage.
- All three growers expressed the need for a pre plant herbicide treatment. Uniform planting rates throughout the field is needed to avoid thin spots where weeds can become established.
- The growers using Sorghum/Sudan grass on their worst fields (gray soils) felt it necessary to broadcast 75 -100 lbs./acre Nitrogen in order for the Sudan grass to grow adequately during the summer.
- In the fields where Sudex had been allowed to grow without mowing, one grower experienced some difficulties with debris clogging up his planter the following spring. It is very important to disk and plow down the Sudex early (first two weeks of Sept.) in the fall to avoid this problem.
- The growers were surprised to see the impact of mowing the Sorghum/Sudan grass. All three growers are convinced of the cover crop's merits. All three said they will continue to utilize Sorghum/Sudan grass on roughly 20% of their acreage in the future.

1995 Trials

- One participating grower planted his earliest onions on a field that had last year been in Sudex. (Previously, he had planted the Sudex fields later in the spring) The onions were paler in color. The grower also felt these onions were not as well along as onions on other ground. We decided it was because of the cold spring weather. The Sudex debris was taking up nitrogen as it was breaking down. Once soil temperatures warmed up, more nitrogen was released from the soil and the onions caught up.
- Fields that were mowed multiple times had turned into "grass". The stems were green and not very thick. The roots had become fibrous. The roots only stayed in the top 4 - 6 inches of soil. In the multiple mowed fields, once the growers attention was focused on harvesting, the plants reached 4 - 5 feet in height in early September. Most fields had been mowed 2 to 4 times.
- Sudex plants that had been mowed only once had tillered, making multiple above ground stems. Roots were thick and penetrated down into the soil more than 14 inches. Comparative weights between multiple mowing and single mowing were almost six times the weight, in favor of single mowing.
- Weeds in both the multiple and single mowing fields were not a factor. Early in the season, because the Sudex can be slow to get started, weeds appeared to infest the fields. Later in the season, the weeds remained small and did not form seed.
- A grower concern was too much debris causing clogging problems for his onion seeder that spring. All fields should be disked and plowed down while still green, in early September. The grower that had a problem admitted he had waited till October to disk and plow down his Sudex.
- It would appear, if managed correctly, mowing once is the best option. Deep rooting is the most obvious advantage to single mowing. It is critical for the grower to cut and disk down the Sudex early in September to avoid debris problems the following spring.
- 1995 was the first time we saw the nitrogen deficiency on early planted onions. A wet spring is when the field drainage advantages of Sudex count most. If this advantage is countered by nitrogen deficiency, than it is really no advantage. It may be that the admitted late plowing of the Sudex was the reason for incomplete breakdown and the nitrogen deficiency. That particular grower was the only one who experience the deficiency. Our feelings were the abnormally cool spring temperatures caused the N deficiency.

1996 trials

- The test plot comparison fields were set up side by side. Similar planting dates and the same varieties were employed. Fields were evaluated in the spring, mid season and just before harvest. A major factor during the season was the weather. Hurricane Bertha visited Orange County. Almost 25% of total onion acreage was hailed on and all acreage experienced high winds and heavy rainfall. The weather extremes drastically affected overall quality and yields. Two of the test plots were abandoned after late June. Fortunately, the remaining test plot fields showed good results.
- Onions following Sudangrass showed a 35% increase stand counts and a 20% increase in yield. Quality was at least as good or better in the Sudangrass fields as compared to the continuous onion fields. Given the weather conditions, these results must be considered very good. Talking to growers who employed the Sudangrass rotation, two responses were heard. First, the onions following Sudangrass were the growers best onions and secondly, the growers felt the numbers we found in our test plots were low. For most years, the growers felt they received an even bigger yield response than what we found in the test plots.

1997 trials

- It was a very dry summer. We found an average 26% overall increase in yield. (with a range from 4% to 43%)
- Most significantly, onion stand counts in fields following Sudan grass averaged 73% higher than onions in non rotated fields. Results ranged from 43% to 93% more onions in the Sudan grass rotated fields. The largest number of onions were lost early on, when the small plants did not have adequate root systems to carry through the dry growing conditions. The increased organic matter in the soil and decreased disease pressure, as a result of the Sudan grass rotation, may also explain this result.
- The field with the lowest yield difference had the highest percent difference in stand counts (4% yield increase with a 93% stand count increase). This field was very well drained. The summer of 1997 was very dry. Since Sudan grass increases drainage in soils. On an already well drained, dry soil, Sudan grass rotation on a dry year, will not have significant yield impacts. Growers need to consider field characteristics when using Sudan grass.
- We also wanted to look at the long term positive effects of Sudan grass rotation. We evaluated onion fields two years after a Sudan grass rotation. It appears there is still a significant yield and stand count increase but it is not as great compared to the first year after rotation. We found an average yield increase of 18% and a 13% increase in stand counts. We would like to continue looking at long term effects.
- More and more growers are becoming convinced in the value of Sudan grass rotation. There was an estimated 350 acres of Sudan grass grown last season in Orange County. This number has increased every year. If growers can obtain an increased yield return of 15% to 30% per year following Sudan grass, a 20% field rotation of their land would be more than justified.

Sudangrass cultural recommendations

A grower can put 20% of his fields into Sudan grass rotation each year. With an expected yield return of 15% to 40% from those fields, the grower will be ahead after 5 years and his whole farm will have been rotated. Besides the yield return, the grower can probably save at least 25% on seed costs. Additional savings will be in time, labor and pesticides not used on the 20% out of production each year.

Recommendations

- Plant second or third week of June or after early crop (radish, lettuce, spinach, etc.)
- Plant at 50 lbs. seed / acre - cyclone, than lightly disk.
You need good coverage - don't want bare spots
- If you need fertilizer - 50-75 lbs. N
- Pre-plant weed control - In New York State - Basagram or Duel

- Duel may cause phyto, use label rates
Pre-plant incorporation - very shallow spring tine drag
- Basagram late planting, wait for nutsedge 6" tall, 2 qts basa + oil
2.25 pts. with 2nd application 7-10 days later
- Mow when it gets 2.5 - 3 feet tall. Re-growth will result in increased tillering of roots and increased root penetration depth.
- Chop and till down before frost. If later, you may have trash and or N deficiency problem
- Following year, reduce seed planting rates by 20%

98 Trial results - Other crop rotational comparisons

It almost goes without saying, all four rotational crops gave a yield increase over non-rotation. It always helps to break the same-crop cycle. We've learned from previous years the impact from rotation will be greater the poorer the soil. The better the soil, the less difference you will see between rotation and non-rotation. Still, across the board, rotation gave significant yield and stand count increases in all the comparison plots.

Comparison 1 - Potato rotation

Comparison 2 - Sudangrass rotation, two fields averaged together

Comparison 3* - Lettuce rotation, not comparable soils

Comparison 4 - Spinach rotation

Yield Comparison: When looking at any yield results, the weather conditions have to be considered. The summer of 1998 will be remembered as a very dry one. The dry conditions were favorable, in light of the extreme hail damage, and allowed the young onion plants to re-grow without bacterial problems. The best yield results came from the sudangrass rotation. In total yield, sudangrass was almost 7% higher than the next closest rotation crop (spinach). The percent difference between rotation and non-rotation was also highest with sudangrass, 30% compared to the next best yield increase of 13% with the spinach rotation. Talking to all the growers about the trial, each grower said yield results are not as high on dry years as compared to wet or normal years. Rotated onions will do much better with normal moisture levels. Sudangrass rotated onions will also do better on wet years as water penetration is very much increased with this rotation.

Stand Count Comparison: The stand counts are all greater in rotated fields compared to non-rotated fields. It is interesting to note how all the rotation stand counts range between 110 and 115 plants per 3 ft. of bed. They are consistent. The non-rotation stand counts range from 68 to 104 plants per 3 ft. of bed. With rotation, basically, what's planted is there at the end of the season. With non-rotation, plants are lost because of a variety of disease problems.

Onion Size Comparison: Onion size in relation to rotation is a little harder to analyze. The first thing to look at is the stand count. When the stand count is high, there are more onions and size can be affected. With rotation, the onions are growing with more vigor and sizing up better. In general, size is not that much smaller and the total yield is greater to make up the difference. For example, yield is 30% greater with sudangrass rotated onions averaging 2.4 inch bulbs compared to a 2.55 inch average for non-rotation. The higher stand counts have been consistent with all our previous tests. We feel a 10-20 percent decrease in planting rates after rotation will maintain adequate bulb size.

Fall Cover Crop rotation

Over the last few years, onion bulb mites have increased as a problem. It is felt the mites overwinter on the traditional grass cover crops of oats and barley. This study was an attempt to evaluate fall planted broad leaf cover crops. The fall planted covers we looked at were annual crimson clover, field peas, yellow mustard, hairy vetch and buckwheat. Two growers in the onion growing region of Orange county and one grower from Oswego agreed to supply the muck-land and carry out the trials. Fields were one acre, divided into one-fifth of an acre plots. We evaluated ease of establishment, root depth and bio mass.

The disease and insect cycle needs to be broken by some crop and the reason annual crimson clover, field peas, yellow mustard, hairy vetch and buckwheat were selected for evaluation is because they each have strengths. There may not be a “silver bullet” rotational cover but by looking at different crops, it is possible a specific crop may work for a specific grower.

	<u>Planting date</u>	<u>top growth</u>	<u>root length</u>	<u>cost per acre</u>
Field one	8/30/01			
Field peas		12”	6”	200 lbs./acre - \$150-200
Hairy vetch		7”	5”	40 lbs./acre - \$140
Yellow mustard		21”	5”	10 lbs./acre - \$15
Buckwheat		16”	5”	60 lbs./acre - \$32
Crimson clover		2”	4”	25 lbs./acre - \$80
Field two	9/4/01			
Field peas		8”	5”	
Hairy vetch		3”	2”	
Yellow mustard		13”	4”	
Buckwheat		8”	4”	
Crimson clover		2”	3”	

Conclusions

All the participating growers were surprised at how well the cover crops established in the fall. The growers were also happy someone was looking at this aspect of production and were looking forward to how well the onions performed after each particular cover. The major concerns for the growers were spring trash and volunteer weeds. The field peas grew well into the fall and established a large amount of bio-mass. The yellow mustard produced a carrot like tap root. Mustards are a serious weed for onion growers. While the yellow mustard used in this trial is not the same as the weed species, growers were still weary. Yellow mustard needs long days and warm temperatures to produce seed. Planting the yellow mustard when we did in the fall was giving it short days and cool temperatures. Just the opposite of what it needs for seed production. No weed problems were experienced the following spring. The only spring trash problem we experienced was the spring growth of hairy vetch. The spring growth was very difficult to disk down.

Fall is a busy time of year for onion growers and they are deep into harvest. Grass cover crops are the traditional option for fall establishment. If it is true that mites prefer grass species for winter carryover, than a broadleaf cover crop is needed. The covers chosen for this evaluation were picked because of their ease of establishment.

Brassica Biofumigants for Onion Production

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Brassica cover crops; including oilseed radish, brown mustard, oriental mustard and yellow mustard, have been shown to provide several benefits in many cropping systems. Plants in the mustard (brassica) family produce glucosinolates that are secondary plant metabolites. Upon tissue damage, the glucosinolates are hydrolyzed to form multiple chemicals including isothiocyanate. Isothiocyanate is a volatile toxic compound used as active ingredient in the commercial fumigant Vapam. Brassica cover crops are called “*Biofumigants*” because they have the ability to release isothiocyanate when their tissues are damaged. The process of breaking down brassica tissues and incorporating them in the soil is called “*Biofumigation*”. Biofumigants have helped reduce the populations of nematode, weed, and disease pests when managed adequately in cropping systems. Additionally, these cover crops recycle large amounts of residual nutrients left in the field after harvest of the cash crop. Higher yield and improved quality of many crops, including sugarbeet and potatoes, have been reported in grounds where brassica cover crops were incorporated. Large acreages of brassica cover crops have been planted in many states with the objective of improving soil quality and reducing pest and disease problems. Most studies on brassica cover crops have been conducted on mineral soils and have used the cover crops as green manure before the cash crops (in the same season). Results of those studies do not apply to Michigan conditions for several reasons: 1) most of Michigan onion is produced on muck soils, 2) onion has a long growing cycle, and 3) the growing season in Michigan is short and does not allow a sufficient window to grow the cover crops in spring prior to planting onion. Therefore, the most efficient way to integrate brassica cover crops into onion production systems in Michigan is to plant the cover crops in late summer, incorporated the residue into the ground before the first frost (normally occurring in October), leave the field through winter and finally, plant onions in early spring (April). Because of these major differences in growing conditions, a study on brassica cover crops in onion production under the specific conditions of Michigan was needed.

The Michigan onion industry is valued at \$12.2 million per year. Serious problems that threaten the profitability of onion production include onion thrips, black mold, foliar diseases, and weeds, including broadleaf weeds, grasses, and especially yellow nutsedge. Crop rotations including cover crops are effective ways of managing insects, weeds, and diseases while improving soil fertility.

A field study was established at the MSU Muck Research Farm (Houghton muck) to test the effects of four brassica and sorghum sudangrass cover crops on onion yield, pest suppression, and soil fertility. Brown mustard, yellow mustard, oilseed radish, oriental mustard, and sudangrass were planted in August, 2004 and incorporated into soil in October 2004. A control treatment without a cover crop was also included. Onion was seeded in three double rows raised beds on April 29, 2005. The cover crops were planted again in August 2005 in preparation for the 2006 onion growing season.

RESULTS

Cover crop Biomass

All cover crops produced considerable amounts of biomass in both 2004 and 2005 (Table 1). Biomass production especially for sorghum sudangrass was greater in 2005 than in 2004 because of

warmer temperatures following planting in 2005. Also in 2005, about 5,576 lb/A of biomass was produced in the control plot without cover crops. The large weed biomass is an indication of the amount of weed seeds produced (and returned to the seed bank), that would become serious problems over the following years. Seeds of some of the species present could remain viable in the soil for more than 10 years after their production.

Table 1. Cover crop biomass

Cover crop	Cover crop dry biomass (Lbs/A)	
	2004	2005
Oilseed radish	5068	6092
Oriental mustard	4819	9851
Yellow mustard	4667	7972
Brown mustard	4908	6030
Sudangrass	2147	12167
Control*	NA	5576

* Biomass in control plot is weed biomass.

Weed populations

Common purslane, yellow nutsedge, common pigweed, and wild mustard made up about 95% of the total weeds. The cover crops reduced weed populations in early spring, prior to land preparation. However, there was no long term benefit of using the cover crops on weed populations during the onion growing season. Therefore, none of the cover crops should be used to replace the normal weed control program. By covering the soil and preventing weed germination and new seeds production, the cover crops could help reduce the amount of weed seeds in the soil if used as long term weed management tools.

Soil microorganisms

Prior to this study the ground used had been fallow for many years; therefore there were few plant parasitic nematodes in the soil. Oilseed radish and oriental mustard increased the population of beneficial nematodes and other microorganisms compared with the control (Figure 1). Among the beneficial microorganisms, 80 to 92% were bacterial feeding nematodes. There were more bacterial feeders in oilseed radish and oriental mustard than the yellow mustard, sudangrass, and control treatments.

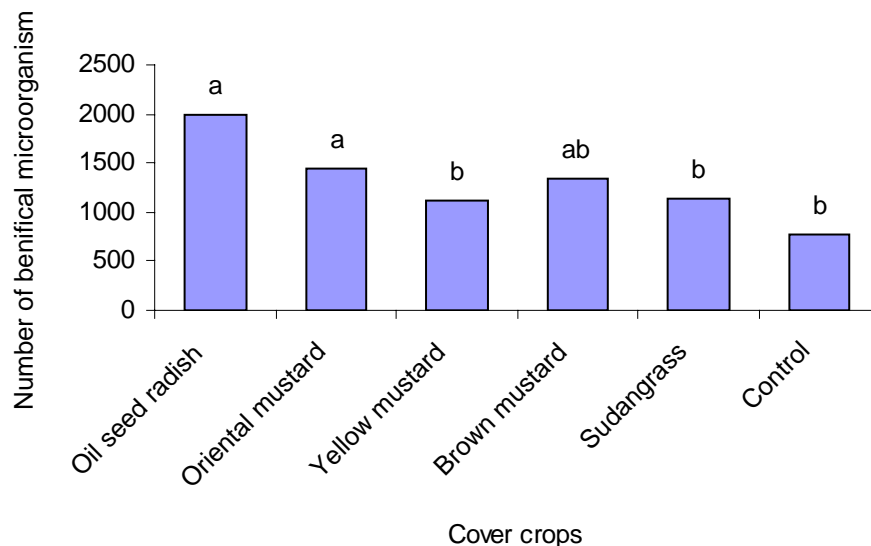


Figure 1. Beneficial microorganisms count per 100 cm³ soil after cover crop

Soil and cover crop nutrient content

In order to assess the capacity of the cover crops to recycle nutrients, total nutrient content of the residue was calculated using tissue analysis results and total cover crop biomass. Most of the brassica cover crops recycled large amounts of N, K, and Ca. Soil analysis showed no difference in nutrient content between the treatments. This is an indication that residual nutrients in the control system were either recycled in weed biomass or lost by leaching.

Table 2. Total nutrient content of the cover crops (Lbs/A)

Treatment	N	P	K	Mg	Ca	S
Oilseed Radish	242.87 a	24.41 b	385.14 a	15.50 b	158.34 ab	45.61 a
Oriental Mustard	250.63 a	37.23 a	398.74 a	22.09 a	175.93 a	45.13 a
Yellow Mustard	227.38 a	22.67 b	343.25 a	15.03 b	140.43 ab	36.99 b
Brown Mustard	100.47 b	10.77 c	104.10 b	13.10 b	28.09 c	7.28 c
Sudangrass	182.31 ab	18.94 b	333.11 a	14.72 b	124.25 b	38.98 ab

Onion yield

Onion yield in all systems was comparable (Table 3). The bare ground system had low plant stand after emergence; a situation that contributed to the production of fewer and larger bulbs. Most cover crops treatments had more bulbs than the control, but due to intra-specific competition bulb size was reduced. This suggests that under appropriate growing conditions, bulb size and total yield could be improved in the cover crop systems by reducing plant density. However, this hypothesis was not been tested in this work.

Table 3. Onion total yield, marketable yield, bulb number, and bulb size per plot (2-m section of the beds)

Cover crop	Total yield			Marketable yield (Grade2+3+4)*		
	Weight (kg/plot)	Bulb number	Bulb size (g/bulb)	Weight (kg/plot)	Bulb number	Bulb size (g/bulb)
Oil seed radish	27.99	236.5	118.8	25.49	188.3	135.7
Oriental mustard	27.40	234.5	116.9	24.31	174.3	139.5
Yellow mustard	28.11	226.8	124.3	25.61	181.0	141.5
Brown mustard	26.50	229.7	115.6	23.94	177.7	134.5
Sudangrass	27.18	229.8	118.3	24.57	178.5	137.8
Control	28.54	218.3	130.7	26.73	183.3	145.8

*Bulb diameter was 0 to 51 mm (grade 1), 52 to 64 mm (grade 2), 65 to 76 mm (grade 3), and greater than 76 mm (grade 4)

Conclusion

The brassica cover crops tested in this work showed excellent potential to increase the populations of beneficial microorganisms in onion production. No immediate benefit in weed control or yield increase was observed during this first year of the study. However, the cover crops could help reduce muck soil erosion by the wind and improve soil quality by increasing the population of beneficial microorganisms. This work will be repeated in summer 2006.

Acknowledgements

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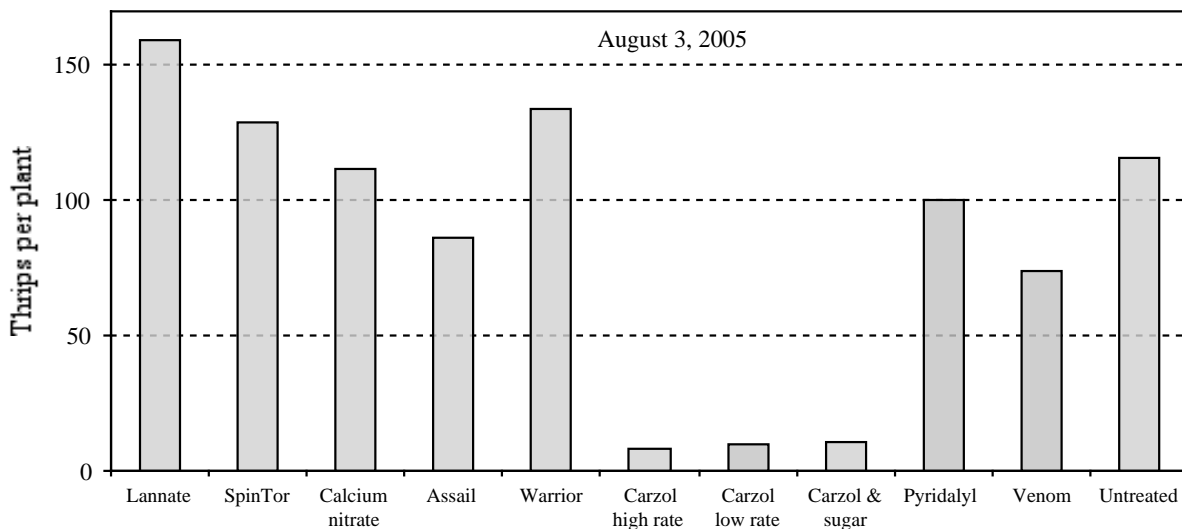
Insect Management in Onions

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Control of onion thrips has become more and more difficult in recent years. This is largely because thrips have developed resistance to many of the common insecticides. In recent years, growers have reported consistent results only with Lannate. In 2005, USDA Interregional Project 4 (IR4) began a cooperative program with researchers to evaluate current and experimental insecticides for control of onion thrips in onions. Research was conducted in the eastern, midwestern, western, and southern U.S. Results showed consistent control problems with pyrethroids and organophosphates and most other products tested. The single product to provide excellent control at all test sites was Carzol, a carbamate commonly used in fruit, but not registered for use in onions.

In the Michigan study, thrips numbers in untreated plots and in most treated plots exceeded 100/plant – this far exceeds the recommended treatment threshold of 10-15 thrips per plant. Carzol at both low and high application rates reduced thrips numbers well below the economic threshold, even though initial thrips populations were extremely high. No other insecticide tested gave consistent control of thrips in this study.

Researchers will continue to work with USDA Project IR4 in 2006 to study control of onion thrips. Emergency use petitions will be submitted to state departments of agriculture and E.P.A. to request approval for Carzol use in 2006. Requirements for registration include documentation of a serious economic problem and establishment of a temporary residue tolerance. Hopefully, with the data collected from several states and the need clearly established, emergency registration will be granted.



Numbers of thrips per plant following insecticide applications on July 20 and 27th.
Thrips numbers in Carzol treatments were significantly lower than in untreated plots.

Iris Yellow Spot Virus of Onion

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Introduction

Iris yellow spot virus (IYSV) is an emerging pathogen of *Allium* crops in the genus *Tospovirus* and family Bunyaviridae. In the US, the virus was first reported in Idaho in the early 1990s, where it was limited primarily to onion seed crops. IYSV has since spread rapidly throughout the western and southwestern US, causing significant yield losses in both onion bulb and seed crops. In 2004, IYSV was reported in *Vidalia* onion crops in Georgia, the first documentation of the disease on the east coast. In the past 5 to 10 years, IYSV has been reported in many other countries, including Australia, Brazil, Chile, Israel, the Netherlands, Peru, Slovenia, and Spain.

Host range of IYSV

IYSV appears to have a fairly limited host range, although this may expand as additional research is carried out. The virus was named *Iris yellow spot virus* because the first detailed description of the pathogen was on iris produced in greenhouses in the Netherlands. Other documented ornamental hosts of IYSV include *Lisianthus*, *Alstroemeria*, and *Eustoma*, and a number of ‘experimental’ host species are used for research purposes, e.g., *Nicotiana benthamiana*. Most *Allium* spp. appear to be susceptible to IYSV, although I am not aware of any reports of garlic crops naturally infected with this virus in the US to date. There is preliminary evidence from H.F. Schwartz’ program at Colorado State University (CSU) that some weed species may serve as asymptomatic hosts of IYSV, including redroot pigweed. This could have significant implications on the epidemiology and management of IYSV in onion crops. Several researchers have been investigating the genetic diversity of the nucleocapsid gene of isolates of IYSV collected from different regions of the world. Different strains of the virus have been found among regions of onion production, and there appears to be some variation in the specific host range of these strains.

Symptoms of iris yellow spot

Iris yellow spot is the disease caused by IYSV in onion crops. Symptoms of iris yellow spot are more easily diagnosed in onion seed crops than bulb crops. Characteristic symptoms in seed crops include diamond-shaped, chlorotic to necrotic lesions on the scape (seed stalk) (**Fig. 1**). The lesions can range in size from <10 mm to >100 mm, and from light sunken lesions to extensive necrotic lesions that may girdle the scape and cause lodging. Some lesions show concentric green diamonds. Symptoms on the leaves resemble symptoms in onion bulb crops. Leaf lesions are less characteristic than scape lesions (**Fig. 2**), and can easily be confused with symptoms caused by powdery mildew of onion (*Leveillula taurica*) (**Fig. 3**) and/or herbicide injury (e.g., from applications of Goal). Leaf lesions usually consist of chlorotic to necrotic, elongated spots that rarely have a concentric, green, diamond-shaped appearance. Severe infections in bulb crops lead to senescence of the leaves, premature maturation of the crop, and reduced bulb size. Symptoms of iris yellow spot can also be observed at the following websites:

- <http://apsnet.org/online/archive/2003/IW000030.asp> (APSnet)
- http://www.cals.ncsu.edu/plantpath/people/faculty/moyer/moyer_jw/posters/iysv/iysv.html (NCSU)

- <http://www.coopext.colostate.edu/TRA/PLANTS/index.html#http://www.colostate.edu/Depts/CoopExt/TRA/PLANTS/iysv.html> (CSU)
- http://mtvernon.wsu.edu/path_team/newsaug04.htm (WSU)

Little is known about the duration of the latent period between infection of plants by IYSV and appearance of symptoms of iris yellow spot. Accurate diagnosis of IYSV in onion crops is dependent on confirmation of infection using lab assays, such as an antibody-based ELISA assay or a polymerase chain reaction (PCR) assay. Several commercial labs provide such assays.

IYSV infection does not appear to be systemic in onion plants. Rather, infection appears to be localized around the site(s) of infection. This may affect the ability to detect the virus when submitting a plant sample for diagnosis. In onion bulb crops, the virus appears to occur in highest concentration in the neck region of plants, probably because the vector of IYSV, onion thrips (*Thrips tabaci*), tends to congregate in the well protected neck. Therefore, whole plants consisting of bulb and leaves should be included in samples submitted for diagnosis. Initial research showed that IYSV is not present in the bulb, basal plate, or roots of onion plants, although researchers at the University of Georgia recently announced that they detected both IYSV and a closely-related virus, *Tomato spotted wilt virus* (TSWV) in the dry outer scales of an onion bulb that showed light concentric rings. Research to date suggests that IYSV is not seedborne or seed transmitted in onion.

Dissemination and survival of IYSV

IYSV can spread and survive in infected host plants and infected onion thrips, the vector of this pathogen. The western flower thrips, *Frankliniella occidentalis*, does not appear to be able to acquire or transmit IYSV. Furthermore, onion thrips only acquire IYSV by feeding on infected plants at the second instar during their life cycle. However, once an onion thrips acquires IYSV, it remains viruliferous for life and can transmit the virus whenever it feeds. The virus is not passed on to the next generation through the eggs. Very little is known about the duration of feeding required for onion thrips to acquire or transmit the virus.

IYSV can survive on infected volunteer onion plants, and in infected thrips overwintering on onion plants or in other crops. Onion thrips has a very broad host range (>300 plant species), making it very difficult to manage the vector. Some onion transplants shipped into Colorado from the southwest have been demonstrated to be infected with IYSV and infested with onion thrips. Movement of infected transplants may have a significant effect on establishment of the virus in various regions of onion production.

One of the factors that may have promoted rapid establishment and dissemination of IYSV in the western US is the prevalence of onion 'green bridges'. For example, biennial onion seed crops are grown on 700-1,000 acres annually in central Washington, the same region where 16,000-18,000 acres of annual onion bulb crops are produced. Compounding this is the presence of infected volunteer onion plants, and the overlap of fall-seeded bulb crops and spring-seeded bulb crops in some areas. Infected volunteers and transplants may account for rapid dissemination of IYSV in onion bulb crops in Colorado, where very little (if any) onion seed is produced. The overall result of these green bridges is a continuous presence of IYSV, which promotes survival and dissemination of the virus and vector.

Other factors that promote development of IYSV

Empirical evidence in multiple states, together with research carried out by H.F. Schwartz' program at CSU, has demonstrated that IYSV tends to be more severe in onion crops that have poor stands, and in crops under stress (particularly moisture stress in the hot and dry growing conditions of the semi-arid western states). The unfavorable effects of overhead irrigation on thrips may explain why iris yellow spot tends to be less severe in onion bulb and seed crops grown using overhead irrigation vs. furrow or drip irrigation.

Impact of IYSV on onion crops

a) Onion bulb crops

The impact of IYSV on onion bulb crops can vary widely depending on growing conditions, management practices implemented by the grower, cultivar planted, source(s) of infection, and maturity of the crop at the time viruliferous thrips migrate into the crop. The main impact of IYSV on onion bulb crops is a reduction in bulb size, as demonstrated by the 2004 Washington State University Onion Cultivar Trial (**Fig. 4** and **Fig. 5**). The furrow-irrigated bulb crop in which this trial was located in central Washington succumbed to a severe outbreak of IYSV. Iris yellow spot incidence and severity (latter on a scale of 0 to 3, where 0 = no symptoms, 1 = few lesions, 2 = moderate lesions, and 3 = severe lesions with the newly emerged leaves appearing necrotic) were rated for replicated plots of the 46 cultivars. Yield (total and by bulb size) was measured for replicate plots of each cultivar. All cultivars proved susceptible to IYSV, with the mean incidence of symptomatic plants ranging from 58 to 97% for individual cultivars. However, significant differences in susceptibility to IYSV were observed among cultivars, despite a distinct gradient in incidence and severity of symptoms across the trial (**Fig. 4**). **Fig. 5** shows the mean marketable yield of all 46 cultivars, placed in the same order of increasing iris yellow spot incidence ratings as displayed in **Fig. 4**.

Averaged over all 46 cultivars, the regression relationship between yield and % plants infected with IYSV was:

$$\text{Bulb yield (tons/acre)} = 33.45 + B_0(\text{cultivar}) - 0.11X_1 - 0.14X_2 - 0.12X_3,$$

$$R^2 = 0.88 \text{ and } CV = 12.1$$

33.45 = mean base yield (tons/acre) for all 46 cultivars.

$B_0(\text{cultivar})$ = inherent genetic difference between the mean base yield and the yield of a specific cultivar.

X_1 , X_2 , and X_3 = % plants with mild, moderate, and severe iris yellow spot symptoms, respectively (severity ratings of 1, 2, and 3, respectively).

This regression shows that, under the conditions of this trial and for these 46 cultivars, yield decreased 0.12 to 0.14 tons/acre for every 1% plants with moderate or severe symptoms of IYSV.

In addition, the percentage colossal (>4" diameter) and jumbo (3-4" diameter) bulbs was significantly affected by the incidence of iris yellow spot:

$$\% \text{ colossal + jumbo bulbs} = 16.38 + B_0(\text{cultivar}) - 0.15X_1 - 0.17X_2 - 0.18X_3,$$

$$R^2 = 0.83 \text{ and } CV = 34.4$$

16.38 = mean base % colossal + jumbo bulbs for all 46 cultivars.

$B_0(\text{cultivar})$ = difference between base % colossal + jumbo bulbs and % for a cultivar.

X_1 , X_2 , and X_3 = % plants with mild, moderate, and severe IYSV symptoms, respectively (severity ratings of 1, 2, and 3, respectively).

For every 1% plants with mild, moderate, or severe symptoms of IYSV, the number of colossal and jumbo bulbs decreased by 0.15, 0.17, or 0.18%, respectively. Correlation coefficients of yield with incidence and severity of iris yellow spot showed the same negative impact of the virus on yield, both in terms of bulb size and tons/acre (**Table 1**). These results concur with other research (e.g., by H.F. Schwartz at CSU) demonstrating reduction in bulb size from IYSV.

Table 1. Pearson's correlation coefficients for mean yield (tons/acre) and % bulbs by class size with the incidence and severity of iris yellow spot in the 2004 Washington State University Onion Cultivar Trial.

Yield	Mean % plants with iris yellow spot symptoms			
	Total	Mild symptoms	Moderate symptoms	Severe symptoms
Total (tons/acre)	-0.43**	0.31*	-0.36*	-0.40**
Size (% of bulbs)				
Colossal (>4")	NS	NS	NS	NS
Jumbo (3-4")	-0.41**	0.40**	-0.40**	-0.44**
Medium (2.75-3")	0.36*	NS	0.33*	0.31*
Small (<2.75")	0.35*	-0.43**	0.37*	0.47**

* and ** = statistically significant at $P = 0.05$ and 0.01 , respectively. NS = correlation was not significant ($P > 0.05$).

One of the difficulties in assessing onion cultivars for resistance to IYSV is separating resistance (or tolerance) of the cultivars to thrips feeding injury from resistance to the virus. In an attempt to gain some measure of the two types of resistance, insecticide treated and non-treated plots were set up for each of 49 cultivars in the 2005 WSU Onion Cultivar Trial in central Washington (**Fig. 6**). Although thrips numbers were high, IYSV was not observed in the trial. Some cultivars appeared to be tolerant of thrips feeding injury, as these cultivars produced similar yields in the treated and non-treated plots. However, other cultivars (e.g., Charismatic, Rancho, Montero, Maverick, 9003G, Talon, and W-10) had much lower yields in non-treated plots compared to insecticide-treated plots. Understanding the potential resistance or tolerance of specific cultivars to thrips feeding and IYSV may help growers select appropriate cultivars to plant, depending on the risk of IYSV infection in their region.

b) Onion seed crops

Although IYSV has not been demonstrated to be seedborne, the virus can cause significant reductions in seed yield. In July 2004, an open-pollinated, direct-seeded onion seed crop in the Columbia Basin of Washington was diagnosed with a severe outbreak of IYSV approximately one month prior to harvest. A distinct gradient in incidence and severity of IYSV was observed across the field, with more severe infection towards the western edge of the crop. Incidence and severity of iris yellow spot were recorded in replicated plots in the western and eastern sections of the crop on 27 July 2004. Severity of iris yellow spot was recorded for each plant on a scale of 0 to 4, where 0 = no symptoms, 1 = 1 to 2 small lesions on the scape, 2 = >2 medium-sized lesions on the scape, 3 = lesions coalescing on the scape, and 4 = scape lodged as a result of iris yellow spot lesions. Umbels were harvested from each plot. The seed was cleaned and weighed, and germination assays completed. Seed yield was significantly lower in the eastern half of the field (24% of the plants had symptoms of iris yellow spot and 7% were lodged) compared to the western half (81% of the plants had symptoms and 20% were lodged) (**Table 2** and **Fig. 7**). Seed germination did not appear to be affected by IYSV, but a lot of seed was culled because of poor seed fill and development on infected plants. Regression analysis showed that for each 10% incidence of plants with symptoms of iris yellow spot, seed yield was reduced 6%. In addition, the seed company reported a final yield of ~200 lb/acre after cleaning the seed, compared to typical yields of 800-1,000 lb seed/acre recorded for this cultivar produced in the same region under similar production practices in previous years.

Table 2. Impact of IYSV on yield of an open-pollinated onion seed crop in Washington State.

Location of plots (severity of IYSV)	Incidence of symptomatic plants (%)	Incidence of lodged plants (%)	Mean severity of IYSV (0 to 4)	Seed yield/umbel (g)	Seed germination (%)
East (moderate)	24.0 a	6.5 a	0.53 a	1.1 a	92.9 a
West (severe)	80.8 b	20.0 b	1.98 b	0.6 b	91.1 a

Numbers followed by the same letter within a column are not significantly different ($P < 0.05$).

A 12-acre, furrow-irrigated, hybrid onion seed crop planted in the Columbia Basin in July 2004, developed severe symptoms of iris yellow spot within 2 months of planting. The seed crop was located <1 mile from several bulb crops infected with IYSV. Plants of the female line had a low incidence and severity of iris yellow spot, but the male line has many severely stunted plants. The entire crop, with an estimated value of \$100,000, was abandoned within 3 months of planting. These examples illustrate the significant potential impact of iris yellow spot on onion seed production in the USA, and concur with similar reports from Brazil and Israel.

Management of IYSV

Effective management of IYSV in onion bulb and seed crops is largely dependent on effective management of onion thrips. However, efforts to control onion thrips are hampered by rapid development of thrips populations with resistance to conventional insecticides such as organophosphates and carbamates. Efficacy trials with new, 'soft' insecticides such as neonicotinoids [e.g. imidacloprid (Admire, Gaucho, and Provado), thiamethoxam (Platinum, Cruiser, and Actara), and clothianidin (Poncho)], spinosad (e.g., Success and Entrust), and neem extract (e.g., Aza-Direct) have demonstrated the potential value of these products for control of thrips and IYSV. Further research is needed to determine optimum programs for these products, and to generate efficacy data that can support pesticide registration requests.

Research by H.F. Schwartz at CSU has demonstrated that foliar applications of Actigard (acibenzolar-S-methyl), a systemic acquired resistance (SAR) inducing product, significantly reduced yield losses caused by IYSV. They achieved more effective management of IYSV by combining Actigard applications with neonicotinyl insecticide seed treatments and/or foliar applications. A Section 18 registration has been approved for Actigard for control of IYSV in bulb crops in Colorado. Research is in progress to evaluate the potential efficacy of Actigard and/or neonicotinyl insecticides for management of IYSV in bulb and seed crops in Washington, particularly given the extended biennial season through which seed crops must be protected from the vector and virus. Promising results have also been demonstrated by L. Jensen at Oregon State University and H.F. Schwartz on the use of straw mulches for control of thrips in onion bulb crops, particularly when combined with applications of 'soft' insecticides and Actigard, which do not kill thrips predators.

Selection of onion cultivars with resistance or tolerance to thrips and/or IYSV may minimize losses caused by this pest and virus. Evidence from field trials in several states suggests that cultivars with blue-green foliage are more attractive to thrips than cultivars with green foliage. Where possible, growers should avoid planting onion bulb or seed crops in areas with onion 'green bridges'. For seed production, planting bulb-to-seed crops instead of direct-seeded crops may facilitate spatial and temporal isolation of crops. Where possible, growers can implement some production practices that create less favorable conditions for onion thrips, e.g., overhead irrigation instead of furrow irrigation, use of organic mulches, and minimizing crop stress by optimizing irrigation and fertilization programs. As information becomes available on the host range of various strains of IYSV, growers can be more attentive about removing potential alternative hosts of IYSV (e.g., weeds that prove susceptible to IYSV). Research is needed to determine whether fumigating bulbs will reduce the risk of moving viruliferous thrips on bulbs.

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Fig. 1. Symptoms of *Iris yellow spot virus* (IYSV) infection in onion seed crops in Washington State.



Fig. 2. Symptoms of IYSV infection in onion bulb crops in Washington State.

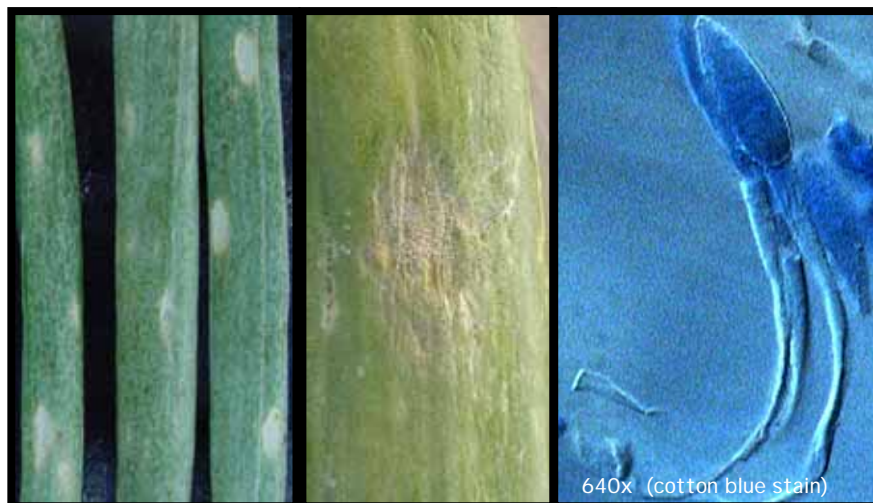


Fig. 3. Symptoms and signs of powdery mildew of onion caused by *Leveillula taurica*. Note the similarity of powdery mildew lesions to iris yellow spot lesions.

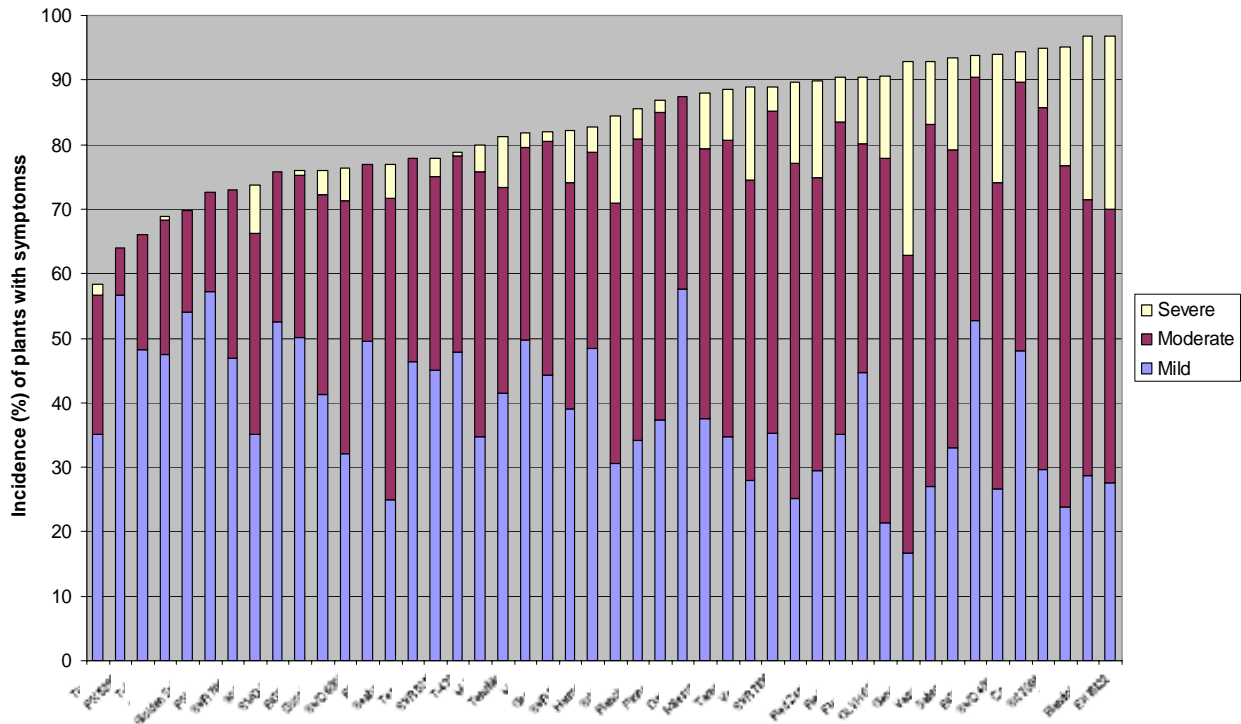


Fig. 4. Mean incidence (%) of IYSV in replicated plots of 46 storage onion cultivars in the 2004 Washington State University Onion Cultivar Trial near Quincy, WA (du Toit & Pelter, 2005. B&C Tests 20:V006).

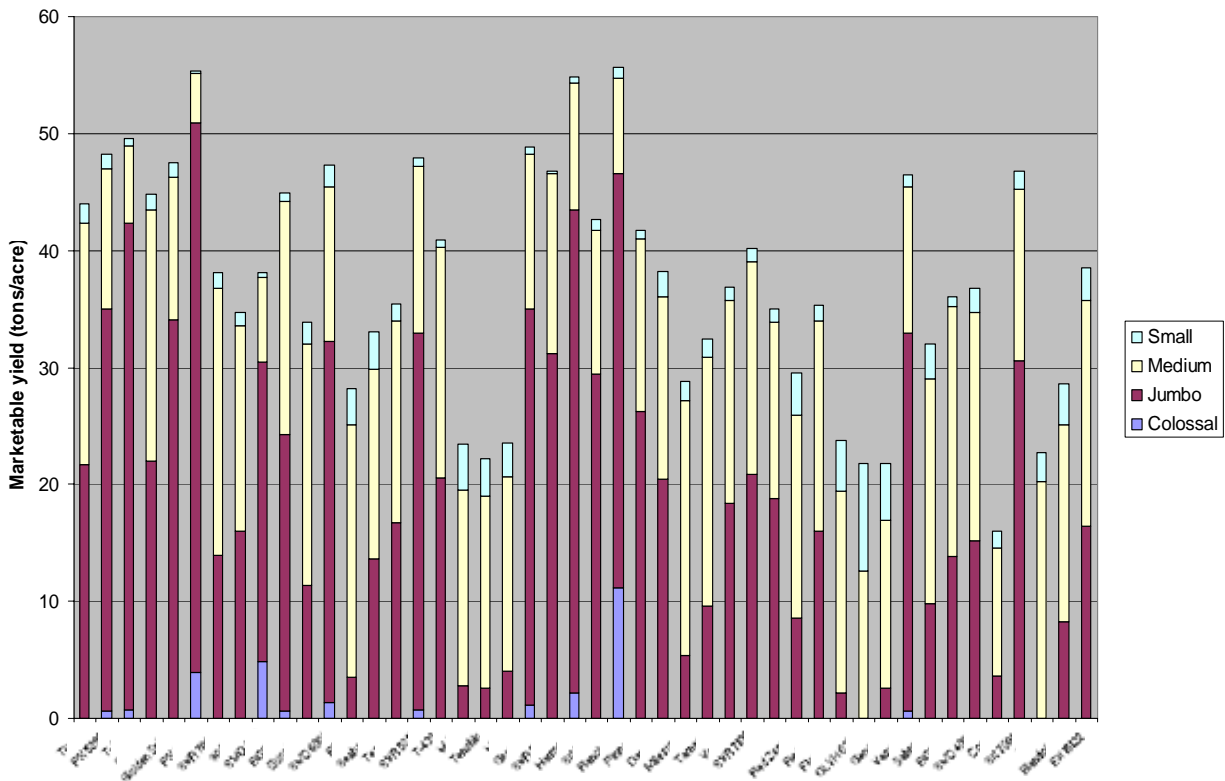


Fig. 5. Mean marketable yield (tons/acre) & number of bulbs by size for 46 storage onion cultivars in the 2004 WSU Onion Cultivar Trial near Quincy, WA (in the same order as Fig. 4) (du Toit & Pelter, 2005. B&C Tests 20:V006).

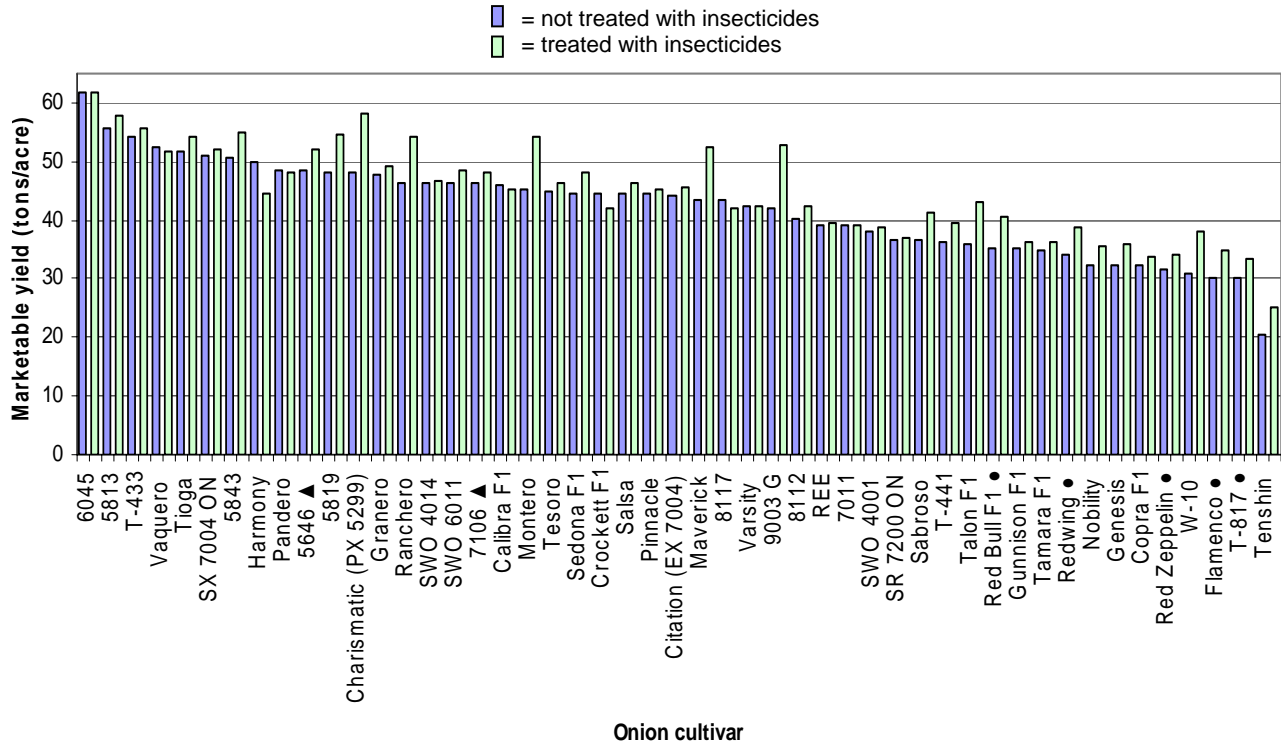


Fig. 6. Marketable yield (tons/acre) of 49 storage onion cultivars treated with insecticides (blue bar) or not treated with insecticides (green bar) in the 2005 WSU Onion Cultivar Trial located near Connell, WA. Results demonstrate the potential tolerance of some cultivars to thrips feeding injury.

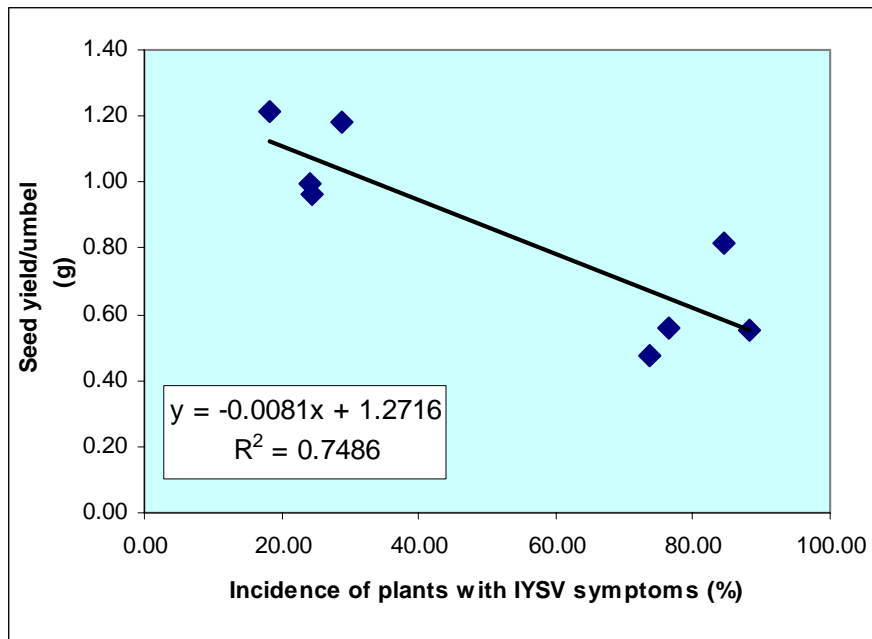


Fig. 7. Relationship between seed yield (g/umbel) and incidence of plants with IYSV in an open-pollinated onion seed crop in the Columbia Basin of Washington in 2004.