CWSS Research Update and News

Information on Weeds and Weed Control from the California Weed Science Society

Volume 15, Number 1 **March 2021**

In This Issue

Introduction

Whitney Brim-DeForest, Editor

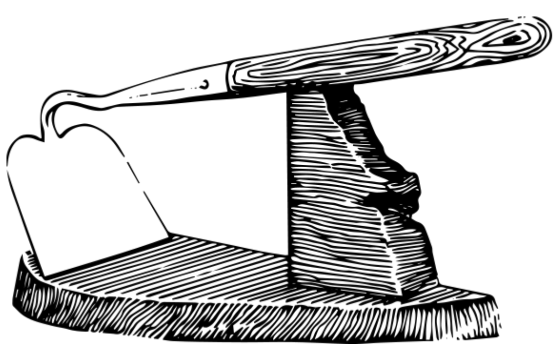
What a year it has been. 2020 was a year for the history books, presenting many challenges, both in our personal lives, as well as in our professional lives. Many of us lost family and friends, and the California Weed Science Society lost a dear friend and colleague. Dr. Travis Bean, whom many of you likely knew, passed away in May 2020. This issue includes a tribute to him.

Despite our challenges, we persevered, learned new methods of communication and how to use unfamiliar technology. Many of us continued our research programs, and this issue includes research updates in orchard crops, alfalfa, lettuce, and pastures, and covers a number of weed species, including broomrape and bearded owl-clover.

Our board of directors put on an entirely virtual conference last month, continuing to provide the latest research and education on weed science in California.

We wish all of you a wonderful 2021, and hope we will see you in person next year in 2022!

-Whitney



Remembering Dr. Travis Bean
(1977 – 2020)

Travis Bean, University of California, Riverside Assistant Cooperative Extension Specialist in Weed Science in the Department of Botany and Plant Sciences, passed away on May 27, 2020. Travis joined the UCR Department of Botany and Plant Sciences in 2014 as a weed scientist with expertise in weed management in wildland, rangeland, and agricultural settings. Travis was an active member of the California Weed Science Society, presenting regularly at CWSS conferences, chairing sessions, serving on the student scholarship committee, and as a judge for the student oral and poster contests. He also served on the Board of Directors for two years, as secretary and vice-president.

The CWSS Board of Directors and Society would like to recognize our colleague and friend, with some of our memories of him. ***Photos courtesy of Travis' mom, Debra Lynn Bean***

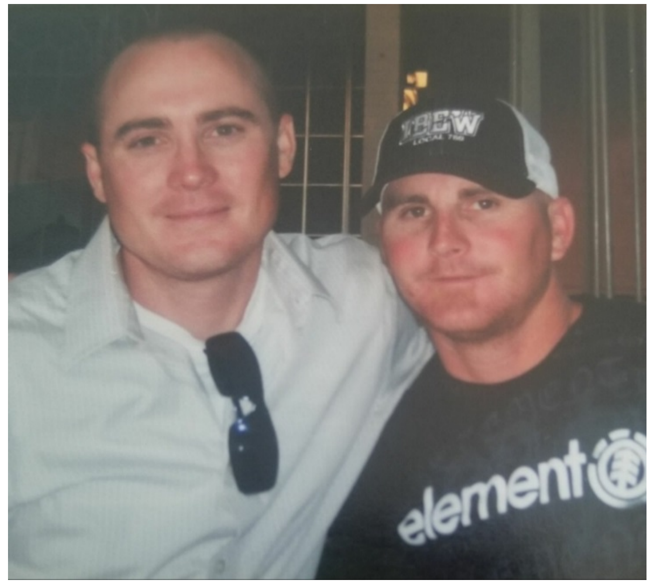
"Although a large state with diverse agricultural systems and wildlands, California has a fairly small academic weed science community. Within a short time after joining the faculty at UC Riverside in 2014, Travis quickly established himself as a key member of the UC "weeders". He was active in the California Weed Science Society serving on the Board of Directors for two years and as a session chair several times. He was also quite visible in the California Invasive Plant Council, a statewide organization focused on weedy plants in the millions of acres of noncrop land in the state. His research and extension program ranged from the southern desert to foothill rangelands in the Sacramento Valley and included diverse topics ranging from weeds in the urban environment, citrus and avocado orchards, roadside and right of ways, invasive rangeland grasses, and forage and fruit crops and general knowledge of herbicides and herbicide application technology. Travis was a great contributor to weed research and extension in California and the western United States and his loss will be felt greatly by his friends and colleagues in the weed science community."

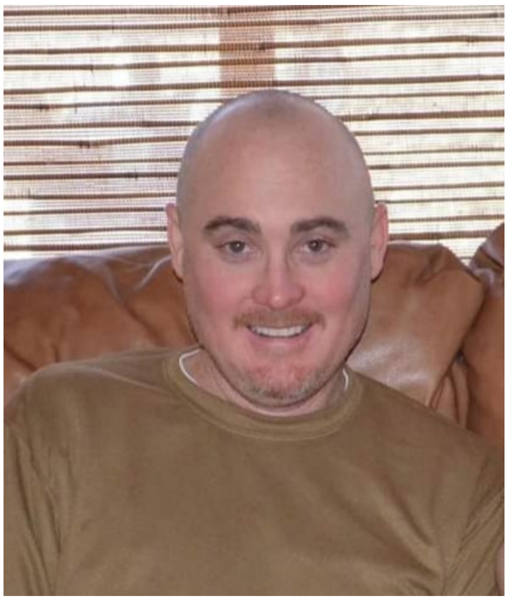
-Brad Hanson, CWSS Past-President

"California weed managers and the discipline of invasive species science lost a great person with Travis's unfortunate passing. I was saddened by the loss of a wonderful friend and fellow weed scientist, far too soon before he should have been taken. In the time I knew Travis, he was always more than willing to lend a hand, or allow you to bend his ear about whatever subject you wanted to explore. I most fondly remember our lengthy conversations swirling throughout the nuances of invasive weed biology, shared over excellent cuisine and a pint. Travis certainly is missed, and was a valuable member of the CWSS!"

– Tom Getts, CWSS Board Member

"I remember meeting Travis when I was a research scientist at UCD and he was a new professor at Riverside. We commiserated about being early career researchers, about finding our paths in the shadows of established scientists, and about being new faces in a new place. We talked about goals and frustrations and future opportunities. We remained in touch even after I changed positions; he kept me updated about his program and asked about mine. I really appreciated that he took the time to check in on me."
-Lynn Sosnoskie, Former CWSS Board Member





"I personally had the opportunity to work with Travis on many research trials and publications throughout the years. He was my colleague and my friend. The short- time I had spent with Travis, was always a positive experience and I will never forget everything he had taught me and I thank him for that. When I first met Travis in 2014, he very quiet and reserved, however after getting the opportunity to really get to know him as Travis and not Dr. Travis Bean, UC Weed specialist, I was given a rare glimpse of the person that not many people get see or know. It hurts and saddens me to know that I will never hear from him, receive a text, or see him again, but I know he is whole again and finally at peace. My heart breaks for his family, especially his mother, Debbie as they were very close and communicated almost on a daily basis. He had other offers to work for different universities, but chose UC Riverside/CE, we're glad he did!"
– Sonia Rios, CWSS member

"When I approached Travis about becoming a CWSS board member and running for Secretary- he didn't hesitate. I remember him saying that it was almost his responsibility as UCCE Weed Specialist and that it would be a great way to get to know more people.

But when I think of Travis one thing always comes to mind. We use the term 'Gentleman" a lot, but few of us are. Travis Bean was a true "Gentle Man."
– John Roncoroni, CWSS past-President

"Travis was not only a great scientist, but a great person. His contributions to weed science in California and to the UC weed science group were immense. But I will always remember him for his sense of humor and easygoing attitude—he got along with everyone and had a way of making others feel comfortable in his presence. I worked with him as Vice Chair when he was Chair of the UC Weed Workgroup, and he was a great mentor to me, as I was just starting out as an Advisor at the time. He also mentored many other early-career Advisors, in his role as the only Weed Specialist based in Southern California. We lost a great friend and colleague in Travis."
-Whitney Brim-DeForest, CWSS Board member

2019 Student Scholarship Award Recipients

Celeste Elliot, CWSS Office Manager

In 2019, the society awarded a total of $10,000 to seven deserving graduate and undergraduate students:

Alex Ceseski (*Photo left*) – University of California, Davis
I am a Ph.D. candidate working with Dr. Kassim Al-Khatib at UC Davis.
My foci are weed management in California rice systems, and the physiology of drill-seeded rice.

Matthew Fatino (*Photo right*) – University of California, Davis
A Master's student at UC Davis, Matthew is in the Horticulture and Agronomy graduate group with an emphasis on Weed Science. Matthew is researching the potential use of the Israeli-developed PICKET decision support system for control of the "A-listed" quarantine pest branched broomrape in processing tomato.

Beth Funke (*Photo left*) - California Polytechnic University, San Luis Obispo
Beth is an undergraduate student at California Polytechnic University at San Luis Obispo, she is studying Agricultural and Environmental Plant Sciences with a concentration in Environmental Horticulture. She is currently working towards getting her PCA license and hopes to pursue a career in ecosystem rehabilitation and weed control in native environments.

Nelly Guerra (*Photo right*) – University of California, Davis
My name is Nelly Guerra and I am a Master's student at UC Davis in the Horticulture and Agronomy Group with an emphasis in Weed Science. My interests include biotic interactions in weed seed physiology and seed bank ecology in strawberry nurseries. My project will include non-fumigant alternatives by using steam to control weed seed emergence and soil pests.

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Steven Haring (*Photo left*) – University of California, Davis
Steven Haring is currently a Ph.D. student at UC Davis working with Dr. Brad Hanson. He is studying weed ecology with the goal of developing integrated weed management programs for almond orchards. After graduation, Steven hopes to work in an extension or outreach career that will allow him to collaborate with growers and improve their farm operations.

Justin Lack (*Photo right*) – California Polytechnic State University, San Luis Obispo
My name is Justin Lack and I am a second-year student at California Polytechnic State University San Luis Obispo. I am studying environmental earth and soil science. I am most passionate about sustainable agricultural practices and how it is related to global humanitarian issues like food insecurity and poverty. I enjoy being outside backpacking, running, and rock climbing.

Not pictured: ***Travis Zuidergaart – California Polytechnic State University, San Luis Obispo***

2020 Student Scholarship Award Recipients

Celeste Elliot, CWSS Office Manager

In 2020, the society awarded a total of $10,000 to ten deserving graduate and undergraduate students:

Maren Appert (*Photo left*) – San Diego State University
Maren Appert is an Undergraduate Student at San Diego State University, graduating in May 2022. She is studying Environmental Science (B.S.) and is in the Weber Honors College. She works with the San Diego Audubon Society (as a Conservation Team Leader and Audubon Advocate) repairing wetland habitat and advocating for the protection of Golden Eagles in San Diego. She also is in San Diego State University's, 'Epsilon Eta', an Environmental Honors Fraternity which (among other things) works to remove invasive species from Rose Canyon and replant oak seedlings. She is passionate about habitat restoration and aims to pursue a career in weed management.

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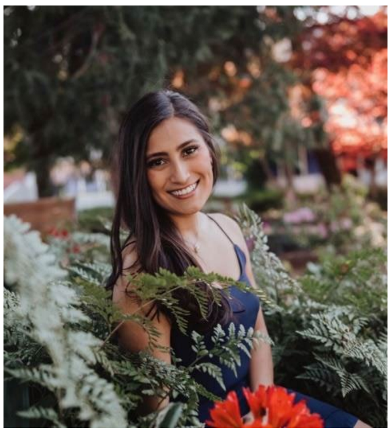
Matthew Fatino (*Photo right*) – University of California, Davis
A Master's student at UC Davis, Matthew is in the Horticulture and Agronomy graduate group with an emphasis on Weed Science. Matthew is researching the Israeli-developed PICKET decision support system for control of the "A-listed" quarantine pest branched broomrape (*Phelipanche ramosa*) in processing tomato.



Kelsey Galvan (*Photo left*) – California State University, Fresno
An entering Master's student at California State University, Fresno in the Plant Science graduate program. Basing my thesis research on the weed waterhemp, focusing on its herbicide resistance to glyphosate. Since it is known to be resistant to more than a few herbicides, by studying the biology and physiology as to why it is resisting any sort of herbicide. In addition, the thesis will include testing other herbicides and their effectiveness, the herbicides of choice are yet to be determined. Currently, I am in progress to earn my CCA and plan to receive my PCA further in the future.

Nelly Guerra (*Photo right*) – University of California, Davis
My name is Nelly Guerra and I am a Master's student at UC Davis in the Horticulture and Agronomy Group with an emphasis in Weed Science. My interests include biotic interactions in weed seed physiology and seed bank ecology in strawberry nurseries. My project will include non-fumigant alternatives by using steam to control weed seed emergence and soil pests.

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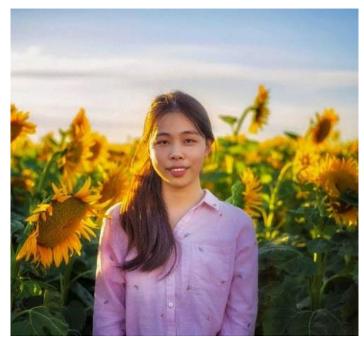
Guelta Laguerre (*Photo right*) – University of California, Davis

Guelta Laguerre is majoring in International Agricultural Development at University of California, Davis. She will be a Master's student next year in Dr. Brad Hanson's lab.

I would like to express my sincere appreciation to the CWSS Board for the $1,000 2020 CWSS scholarship, which has been given to me. I am honored that the board found my application worthy of this award. I sincerely appreciate your generosity and this award will help me a great deal. Thank you so much, and sometimes in the future, I will give it forward. As my favorite quote is "To whom much is given, much is expected."

Alexander Lopez (*Photo left*) – California State University, Fresno

I am a graduate student majoring in Biology at Fresno State. In my thesis work, I am investigating the origins of recently arisen populations of Amaranthus tuberculatus (common waterhemp) in Merced County agroecosystems, using both model-based and non-model-based genetic clustering methods.



Jia Tian (*Photo right*) – University of California, Davis

My name is Jia Tian, and I am a first-year Master's student at UC Davis in Horticulture and Agronomy Group. Currently, I am in Dr. Mohsen Mesgaran's lab using hyperspectral technology to assess the seed quality of weed. My research interest is to apply deep learning in solving environmental problems.

Wenzhuo Wu (*Photo left*) – University of California, Davis

Wenzhuo Wu is a Ph.D. student working with Dr. Mohsen Mesgaran in the Horticulture and Agronomy graduate group at University of California, Davis. She is conducting research to test the viability of a novel approach for managing weeds by pollinating with irradiated and sterile pollen in unisexual breeding systems. Currently, she is exploring an optimal dose of ionizing radiation which can significantly reduce seed production and seed/flower ratio in Palmer Amaranth. She got a drone pilot certificate this July. In the future, she hopes to get a PCA license and contribute to the growing body of scientific knowledge by combining the knowledge from remote sensing, statistics, and weed science.

(continued on Page 8)

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Tong Zhen (*Photo right*) – University of California, Davis

My name is Tong Zhen, a Master's student at the University of California, Davis. I am working with Professor Mohsen Mesgaran and focusing on ecological weed management. My current project is about the automated survey of weed species along the roads.

A Six-year Evaluation of the Cumulative Impacts of Glyphosate Impacts on Orchard crops

Brad Hanson and Adewale Osipitan, University of California, Davis

Glyphosate is one of the most commonly used herbicides in orchard crops in California both in terms of treated acres and the amount of active ingredient applied. Weed managers are generally familiar with the attributes of glyphosate as a postemergence herbicide. Duke and Powles (2008) published an article in Pest Management Science entitled "Glyphosate: a once-in-a-century-herbicide". Suffice to say, it's a pretty useful herbicide if that's your thing. It has also been the subject of several controversies in the past couple of decades.
One of those controversies was a source of frequent extension questions from California farmers and Pest Control Advisors about 10 years ago. In the late 2000s, there were several researcher articles from work done in glyphosate-tolerant soybeans that suggested there might be some nontarget impacts of glyphosate on crop nutrient status, plant disease interaction, and microbial community effects. In California, tree crops concern generally focused around whether glyphosate in the soil could chelate micronutrients and lead to nutrient deficiencies and/or if repeated use could cause enough glyphosate to accumulate in soil and have direct impacts on the trees.

In a 2012 review article on the impacts of glyphosate in the soil environment, Duke et al. suggested that "significant effects of glyphosate on soil mineral content is unlikely" and there is no clear negative trend in orchard productivity data in California even after decades of glyphosate use. However, because this was a concern for the California orchard crop industries, we conducted a long-term research project from 2013 to 2020 to help address the issue in representative orchard crops.

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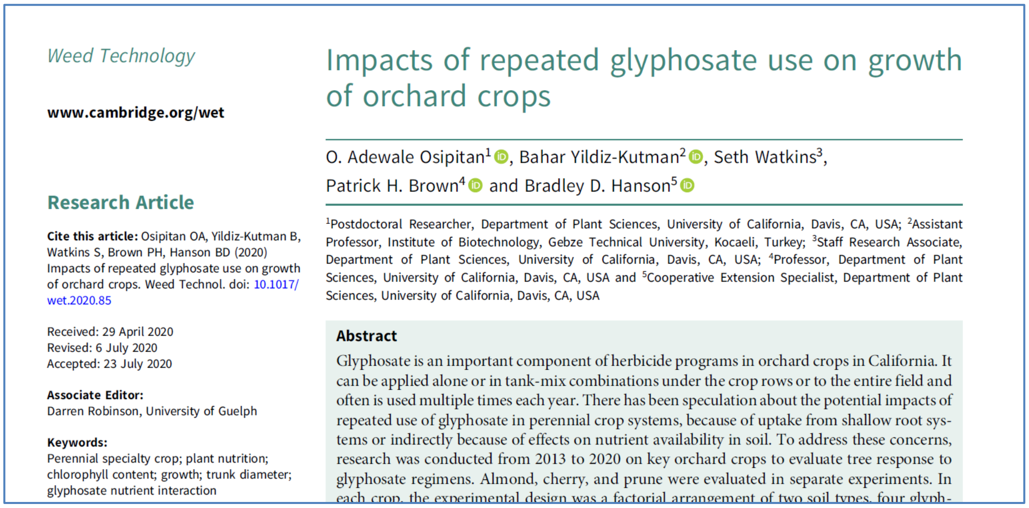
If you're interested, the full report was published in summer 2020 as an open-access article in the journal Weed Technology which can be accessed HERE.



Weed Technology

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Research Article

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Perennial specialty crop; plant nutrition; chlorophyll content; growth; trunk diameter; glyphosate nutrient interaction

Impacts of repeated glyphosate use on growth of orchard crops

O. Adewale Osipitan[1], Bahar Yildiz-Kutman[2], Seth Watkins[3], Patrick H. Brown[4] and Bradley D. Hanson[5]

[1]Postdoctoral Researcher, Department of Plant Sciences, University of California, Davis, CA, USA; [2]Assistant Professor, Institute of Biotechnology, Gebze Technical University, Kocaeli, Turkey; [3]Staff Research Associate, Department of Plant Sciences, University of California, Davis, CA, USA; [4]Professor, Department of Plant Sciences, University of California, Davis, CA, USA and [5]Cooperative Extension Specialist, Department of Plant Sciences, University of California, Davis, CA, USA

Abstract

Glyphosate is an important component of herbicide programs in orchard crops in California. It can be applied alone or in tank-mix combinations under the crop rows or to the entire field and often is used multiple times each year. There has been speculation about the potential impacts of repeated use of glyphosate in perennial crop systems, because of uptake from shallow root systems or indirectly because of effects on nutrient availability in soil. To address these concerns, research was conducted from 2013 to 2020 on key orchard crops to evaluate tree response to glyphosate regimens. Almond, cherry, and prune were evaluated in separate experiments. In each crop, the experimental design was a factorial arrangement of two soil types, four glyph-

If you're only a little interested, here is the essence of the project conduct at the UC Davis Plant Sciences Field Facility in Davis, CA:

- Crops (three crops were considered separate experiments):
  - Almond (Nonpareil on Lovell)
  - Prune (Improved French on Lovell)
  - Cherry (Coral on Emla-Colt)
- Planting site:
  - At planting, all tree sites were excavated with a 36-inch diameter auger to a 2-ft depth
  - Half were refilled with the native silty clay loam soil
  - Half were refilled with Delhi sandy loam
- Glyphosate treatments:
  - From 2014 to 2019, treatments were applied 3 times per season (~between Apr-Nov)
  - Rates were 0, 1, 2, or 4 lb ae/A equivalents (Roundup PowerMAX plus ammonium sulfate). Applied to an area of about 6x6 ft around each tree
  - In 2014, trunks were protected with cartons, but no trunk protection in 2015-19

(continued on Page 10)

(continued from Page 9)

- Drench
  - In the first two years of treatment (2014 and 2015), there was a split-plot factor in which half of the trees had a small berm built up around the base of the tree and were "drenched" with water to simulate 1-inch irrigation immediately after each application (intended to increase leaching into the relatively small tree root zone and crown area).
- Evaluations
  - In the first year of treatment (2014) leaf samples were collected 14 days after each glyphosate application and assayed for shikimate accumulation (which would indicate direct herbicidal effects of glyphosate).
  - In the first two years of treatment, relative chlorophyll content was measured in leaves from each tree 30 days after each glyphosate application (which could indicate either direct glyphosate effects or indirect effects of micronutrient limitations).
  - Trunk diameter measurements were made before the first application in 2014 and during the winter after each subsequent season to evaluate relative tree growth.
  - After the 6th year of treatment, leaf samples were collected in the fall from each tree but combined over soil type and drench subplots. The nutrient status of these leaf samples was determined by the UC Davis Analytical Lab using appropriate techniques.

- So, to recap, the worst-case scenario had:
  - Very coarse soil in the planting site of bare root almond, cherry, and prune nursery trees.
  - In the first two years, some plots had a simulated acre-inch of irrigation immediately following each glyphosate application.
  - The highest rate treatment of 4 lb ae/A glyphosate was applied 18 times over a six-year period. That's 114 fl oz/A of Roundup PowerMAX at each application. Over the course of the experiment that's 72 lb ae/A glyphosate or 16 gallons of Roundup PowerMAX. It's a lot!
- **Results:**
  - Shikimate levels were similar among treated and non-treated trees with no clear dose-response or soil-related parameters. This suggests little or no direct effect of glyphosate on these tree crops via root uptake even at fairly extreme rates over multiple years.
  - Chlorophyll content mostly indicated no differences among treatments. Where there were statistically significant main effects or interactions, there was no consistent pattern with regard to glyphosate rate, coarse soils, and post-treatment drench, which suggests they may be due to random variation or experimental artifacts.
  - Leaf nutrient analysis after 6 years of treatment did not provide evidence of negative impacts on crop nutrient status.

(continued on Page 11)

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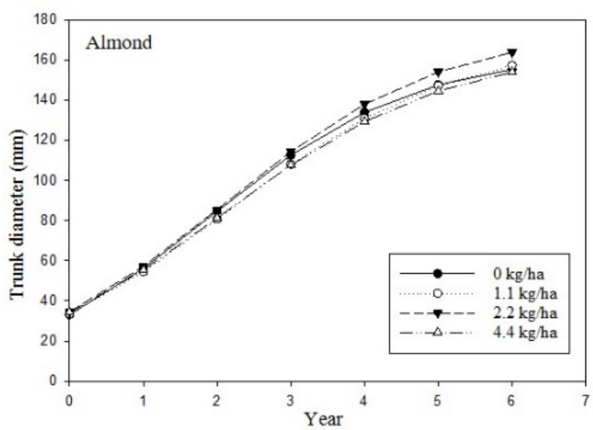
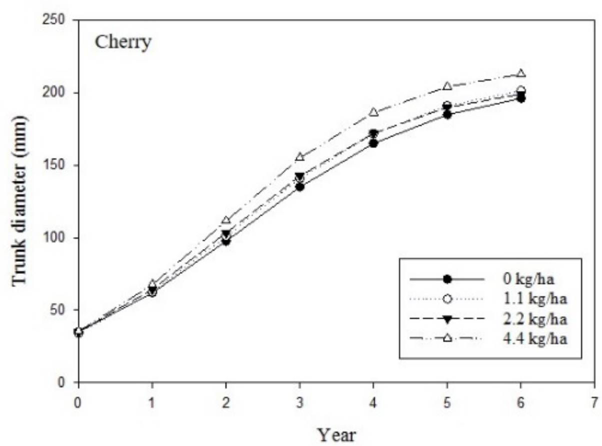
- Trunk diameter increase over six growing seasons was not negatively impacted by glyphosate treatments (Figure).
- Observationally, over the six-year period, there was no evidence of treatment-related trunk cankers, trunk or limb malformations, or unusual die-back.

Scientists will always remind you that you "can't prove a negative", and that remains true. However, we think these data suggest that it is probably not easy or common for almond, cherry, or prunes to be negatively impacted by glyphosate residues in the soil either due to direct herbicide effects or to micronutrient deficiencies.





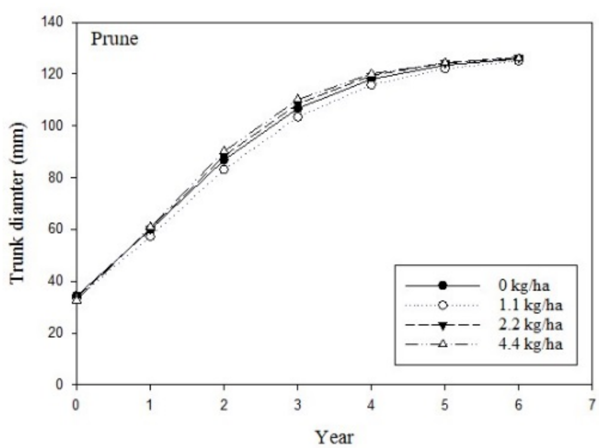


Figure. Orchard crop trunk diameter change over six growing seasons in response to three yearly applications of glyphosate herbicide at high rates (1, 2, and 4 lb ae / acre). The experiments were conducted 2014-2020 near Davis, CA. Trunk data are averaged over two planting site soils (sandy vs silt loam) and a post herbicide application of water (yes or no) in the first two years (n=16 at each data point).

(modified from Osipitan et al. 2020 Weed Technology).

Acknowledgments:
This work was initially supported by the Almond Board of California, the California Dried Plum Board, and with nursery stock provided by Sierra Gold Nurseries. Over time, the experiments were maintained with general program support from the crop protection industry, orchard commodity groups, and agricultural input suppliers. We gratefully thank our colleagues who contributed to this long-term project along the way.

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Biological Characteristics that Make Broomrape a Threat to California Crop Production Systems

O. Adewale Osipitan, Bradley D. Hanson, Matthew Fatino, and Mohsen B. Mesgaran
University of California, Davis

In a previous article we gave a general background of branched broomrape (*Phelipanche ramosa*), a parasitic weed that was the focus of a $1.5 million eradication effort four decades ago in California, and now a re-emerging threat to California processing tomato (link, Figure 1). The threat posed by branched broomrape is different than most agricultural weeds due to its unique life cycle. Understanding its biology is an important first step in providing strategic and sustainable control of this weedy broomrape in California crop production systems.

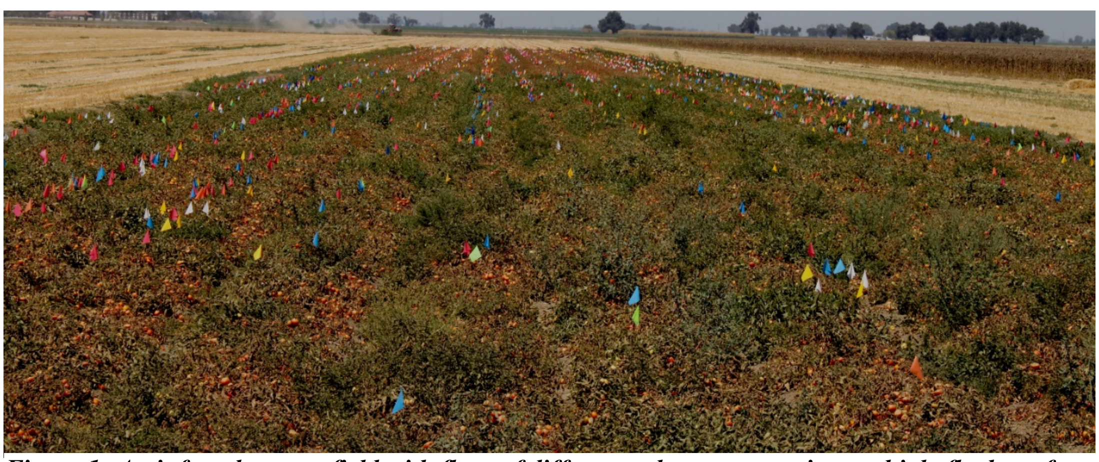

Figure 1: An infested tomato field with flags of different colors representing multiple flushes of branched broomrape captured weekly from May 29, to July 30, 2020 in Yolo County, California. Photo: Fatino

Branched broomrape is an obligate parasite, meaning that all stages of its life cycle, right from germination to seed production depend entirely on the presence of a suitable host plant and a relatively narrow range of environmental conditions.

(continued on Page 13)

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In California, these conditions typically are met within mid-spring to late summer. Before germinations branched broomrape seeds go through a preparatory stage called the pre-conditioning period to break seed dormancy, under a moist and warm field condition with a daily temperature of 60 to 70 ^{o}F for at least 5 to 7 days. This pre-conditioning period often coincides with early tomato planting in many parts of California, that is, mid-spring (March to April). Then, after tomatoes are transplanted, the pre-conditioned broomrape seed can germinate in response to a signaling stimulant (strigolactone) released from the host plant roots (Figure 2). If the field conditions remain conducive, there can be multiple flushes of germination within a single season (Figure 3); however, in the absence of a signal from a suitable host these pre-conditioned seeds may once again become dormant. The ability of the seed to germinate reduces gradually as the field becomes dry, and the possibility of seed germination can be very low when the average daily temperature is greater than or equal to 85 ^{o}F, during late summer.

Figure 2: A germinating seed of branched broomrape stimulated to germinate using a synthetic strigolactone; viewed under microscope in the Contained Research Facility at UC Davis. Photo: Osipitan

After germination, the radicle (immature primary root) of the broomrape seedling grows a few millimeters in length to encounter a host root. If it does not encounter and attach to a suitable host, it is likely to exhaust its energy reserves within a few days. Interestingly, not all plants that release stimulants for branched broomrape germination allow the penetration and connection of this parasite to their system. These plants are called false hosts or trap crops and these may include alfalfa (*Medicago sativa*), cowpea (*Vigna unguiculata*), green pea (*Pisum sativum*), and flax (*Linum usitatissimum*). These trap crops can be used to promote germination of branched broomrape without supporting their survival; thereby, reducing populations of the weed in the soil seedbank.

Following a successful attachment to a host plant such as tomato, the radicle develops into a specialized modified root called the haustorium, a plant organ common to all parasitic plants. The haustorium fuses into the vascular system of the host root and serves as the bridge for the extraction of water and nutrients from the host plant. Once connected to a host plant, broomrape grows rapidly, forming a tubercle underground (Figure 4). The knowledge of the period at which tubercle is being formed is very useful in controlling broomrape. Multiple shoots develop from a single tubercle (Figure 5) and emerge above the soil surface, then grow to 5 to 15-inch tall stalks (Figure 6). The shoots are wrapped with alternate bracts but completely lack leaves and chlorophyll (Figure 6). This lack of leaves and chlorophyll is an indication that branched broomrape lacks the ability to synthesize food by itself, and that weed control inputs such as foliar herbicides have no platform for activity in the parasite.

Once it emerged above the soil surface, branched broomrape rapidly proceeds to the reproductive stage; flowering within 3 to 7 days after emergence. Branched broomrape flowers are spike-like, irregular, bisexual, and usually pale white to purple in color.

(continued on Page 14)

(continued from Page 13)

Figure 3: Different developmental stage of branched broomrape that demonstrates its different flushes in a processing tomato field in Yolo County, California in July, 2020. Photo: Fatino

The petals of the flower are merged, tubular with an upper and lower lip (Figure 7). The carpels are usually united to form a single chamber on the upper part of the flower; this chamber matures as a capsule with thousands of very tiny seeds (0.2 to 0.4 mm), smaller than a grain of sand (Figures 8). Seed production can occur as quickly as two weeks after flowering and a mature broomrape plant can produce hundreds of thousands of tan or brown-colored seeds. The seeds can remain dormant and viable for many years (> 20 years) in soil. These tiny seeds are easily spread through wind, water, animals, contaminated farm implements, and produce. Branched broomrape life cycle from seed germination to seed production is within the March to early September growing season of processing tomatoes in California.

Conclusion

Effective control of broomrapes is difficult, largely due to their unique biology and complex life cycle. As indicated above, most of the broomrape life cycle occurs below the soil surface, which makes it difficult to detect and control before it causes damage to the host plant. The short time period between emergence and seed dispersal also makes detection and control difficult, while the absence of chlorophyll and photosynthesis limits potential herbicide target sites and complicates chemical management of the weed. The hard-to-detect, abundant, tiny seeds and the ability of the seeds to remain viable for decades, promote the spread and persistence of branched broomrape in crop production systems.

Figure 4: Tubercles of branched broomrape attached tomato root, ~40 days after transplanting tomato; monitored in a rhizotron at CRF University of California. Photo: Osipitan.

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Thus, effective management of broomrape requires a long-term integrated approach that involves a sound understanding of its localized and general biology. Herbicide programs for management of a related species, Egyptian broomrape have been developed in other countries based on the understanding of the parasitic weeds lifecycle. University and industry research is ongoing in California to develop similarly-effective practices for the California processing tomato industry (link).

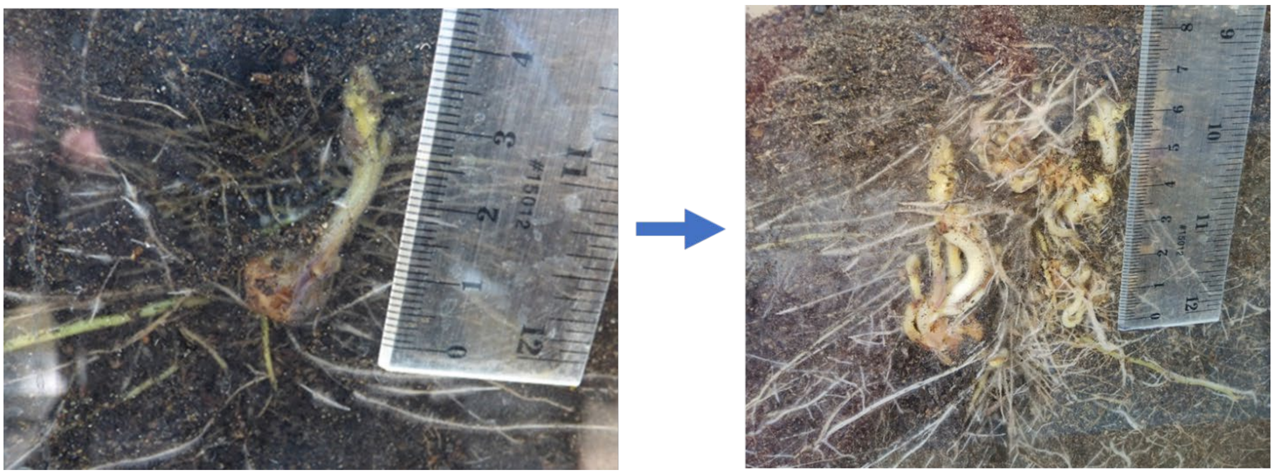

Figure 5: Left; a single shoot emerged from a tubercle of branched broomrape, approximately 60 days after transplanting tomato. Multiple shoots later emerged few days (3 to 5 days) later. Photo: Osipitan.

Figure 6: Branched broomrape plant parts below and above the soil surface. Photo: Osipitan.

Figure 7: A branched broomrape plant: flowering (left), maturing (center) and mature capsules (right). Photos: Osipitan

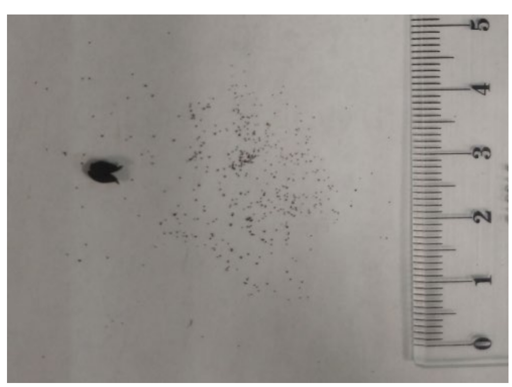

Figure 8 (left): Tiny branched broomrape seeds (0.2-0.4 mm) and the single capsule from which the seeds were sourced. Photo: Osipitan

Preliminary Note for Control of Episodic Bearded Owl-clover (*Triphysaria versicolor*) Bloom in Organic Pastures

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ABSTRACT

Triphysaria versicolor, Bearded Owl-clover, is an annual herbaceous plant, and a root parasite that can parasitize a broad range of host species. It is found along the Pacific coast from Southern British Columbia to central California. Little research has been done regarding Bearded owl-clover in the United States. Most published reports are regarding Bearded owl-clover populations in Canada. More work is needed to determine the economic impact Bearded owl-clover has on coastal grazing lands and proper management methods for control when it occurs in undesirable quantities. A mini-case study for the management of Bearded owl-clover was conducted on private lands in Humboldt County, Calif., and included 3 treatments: grazing, grazing plus mowing, and a control with no manipulation. For each treatment, percent cover was estimated for Owl-clover, grasses, other forbs, and bare ground plus litter. Additionally, the biomass of Owl-clover and grasses plus other forbs was measured at the beginning and end of the study. For both the grazing and grazing plus mowing treatments, the percent cover of Bearded Owl-clover decreased without significantly decreasing the percent grasses cover. For both treatments, kg per ha of Owl-clover decreased while Owl-clover biomass increased in the control transect. Little re-growth of the Owl-clover was observed after clipping or grazing; suggesting grazing may be an adequate tool in reducing Owl-clover abundance on livestock pastureland. Owl-clover appears on specific pastures episodically, every decade or so when properly timed flooding initiates blooms. Therefore, this trial could not be replicated over space or time for statistical analysis; however, this project provides novel information not found in the literature.

INTRODUCTION

Triphysaria versicolor, Bearded Owl-clover or Yellowbeak Owl's-clover, appears along the Pacific coast from central Oregon to central California and a small area of southeastern Vancouver Island in British Columbia (COSEWIC, 2011). In Canada, Owl-clover is restricted to coastal areas occurring in rocky and moderately shallow soils; favoring vernal meadows and seepage areas (Penny and Douglas, 1999). Habitat conditions of salt spray, wind, summer drought, and winter seepage combine to prevent trees, shrubs, and robust herbs from becoming established, which allows the vegetation to be dominated by grasses and forbs (Parks Canada Agency, 2006). Most reports on Bearded Owl-clover populations were conducted in Canada, where the plant is considered an endangered species; however, population trends in Canada are unknown.

Bearded owl-clover has two subspecies, *versicolor,* and *faucibarbatus* and is an annual herbaceous plant with tiny hairs on the leaves and stems with leaves pinnately divided into linear segments (Parks Canada Agency, 2006). The inflorescence has a spike of white or pink flowers, club-shaped corollas, and leaf-like bracts (Penny and Douglas, 1999). Bearded owl-clover germinates in the early spring, flowers in April and May, and dies in late May or June with the summer drought (COSEWIC, 2011). Seed dispersal from the dried plants continues through summer and autumn until the first rains break down the dead plant shoots (COSEWIC, 2011). Bearded owl-clover is a root parasite that can parasitize a broad range of host species. Owl-clover is capable of producing its own photosynthates but also extracts water and nutrients from host plants (COSEWIC, 2011).

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It is capable of maturing without a host plant; however, the Owl-clover's growth is more vigorous with access to a host species. Grasses are a favored host, and Owl-clover has been shown to significantly reduce the dry mass production of grasses (COSEWIC, 2011; Marvier, 1998). The reduction in productivity of grasses due to the presence of Owl-clover is of concern to livestock ranchers utilizing rangeland for haying and grazing purposes.

METHODS

The study was conducted in Humboldt County, CA, over a 1 mo. period and included 3 treatments for the management of Bearded Owl-clover: grazing, grazing plus mowing, and a control. For each treatment, a 12 m transect was monitored at the beginning and end of the study using six 1 m x 1 m frames per transect. For the grazing and grazing plus mowing treatments, cattle were stocked at 44 animal units in a 24 ha pasture (1.9 AU/ha) and were allowed to graze the treatment transects for the entirety of the study.

The grazing plus mowing treatment transect was clipped by hand at the start of the study, which simulated a mowing treatment. The control transect was fenced, and cattle were not allowed to graze the control treatment (Fig. 1). For each treatment, percent cover was estimated for Owl-clover, grasses, other forbs, and bare ground plus litter at the beginning and end of the study. Dry matter production of Owl-clover and grasses plus other forbs was measured by clipping, drying, and weighing the grazing plus mowing transect at the start of the study for initial weights, and by clipping and weighing all transects at the end of the study for post-treatment weights.

Figure 1. Bearded Owl-clover (Triphysaria versicolor) targeted in this study (upper left and right images), and the control transect at the end of the study (bottom image).

Due to lack of replication, preliminary data were analyzed using summary statistics in Microsoft Excel (2016). Percent cover data was averaged for Owl-clover, grasses, other forbs, and bare ground plus litter. The Owl-clover and grasses plus other forbs biomass measurements were expressed as kg per ha.

RESULTS

For both the grazing and grazing plus mowing treatments, the percent cover of Bearded Owl-clover decreased without decreasing the percent grasses or other forbs cover when compared to the control treatment (Table 1). Although grasses numerically decreased for each treatment, there appeared to be no difference between the initial and final percent cover for the grazing and the grazing plus mowing treatments.

(continued on Page 18)

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The percent cover of other forbs numerically increased for the grazing and grazing plus mowing treatments, while there appeared to be no change in forbs for the control treatment. The percent of bare ground plus litter increased for both the grazing and grazing plus mowing transects. Percent of bare ground plus litter slightly increased for the control treatment.

Final kg per ha of Owl-clover decreased for both the grazing (480 kg/ha) and the grazing plus mowing (110 kg/ha) treatments from the initial 1043 kg per ha average. For the grazing transect, 54% of the final biomass consisted of Owl-clover, while only 27% of the final kg per ha consisted of Owl-clover in the grazing plus mowing treatment. The Owl-clover did not recover rapidly from clipping, as shown through the little regrowth observed. In the control transect, kg per ha of Owl-clover increased to 1590 kg per ha compared to the initial value of 1043 kg per ha, and 65% of the final plant composition consisted of Owl-clover.

Compared to the initial value of 113 kg per ha, there were numerical increases in the final kg per ha of grasses plus forbs for the grazing (403 kg per ha) and grazing plus mowing (300 kg per ha) treatments. However, there was an increase from the initial grasses plus forbs for the control treatment to 863 kg per ha, suggesting the host species can survive and grow during Owl-clover infestations. There was little difference in the number of grasses plus forbs between the grazing and grazing plus mowing treatments. Grasses plus forbs totaled less than 10% of the initial kg per ha, while Owl-clover made up 90% of the initial plant composition. Although grasses plus forbs had increased to 35% of the final kg per ha in the control transect, Owl-clover maintained most of the species composition (Fig. 2). Due to the episodic nature of the blooms of this plant in north coast hay and pasture lands, replications have not been possible but would improve the ability to analyze these data.

Table 1. Means of percent cover for Bearded Owl-clover, grasses, other forbs, and bare ground plus litter for the date by treatment.

	Treatment Plot								
	Grazing			Grazing plus mowing			Control		
Cover Type	Initial mean	Final mean	SD	Initial mean	Final mean	SD	Initial mean	Final mean	SD
Bearded Owl-clover (%)	59	25	18	50	6	23	43	47	15
Grasses (%)	24	18	11	43	34	21	24	10	10
Other forbs (%)	15	25	10	6	14	5	30	32	14
Bare ground plus litter (%)	2	32	17	1	46	25	3	12	6

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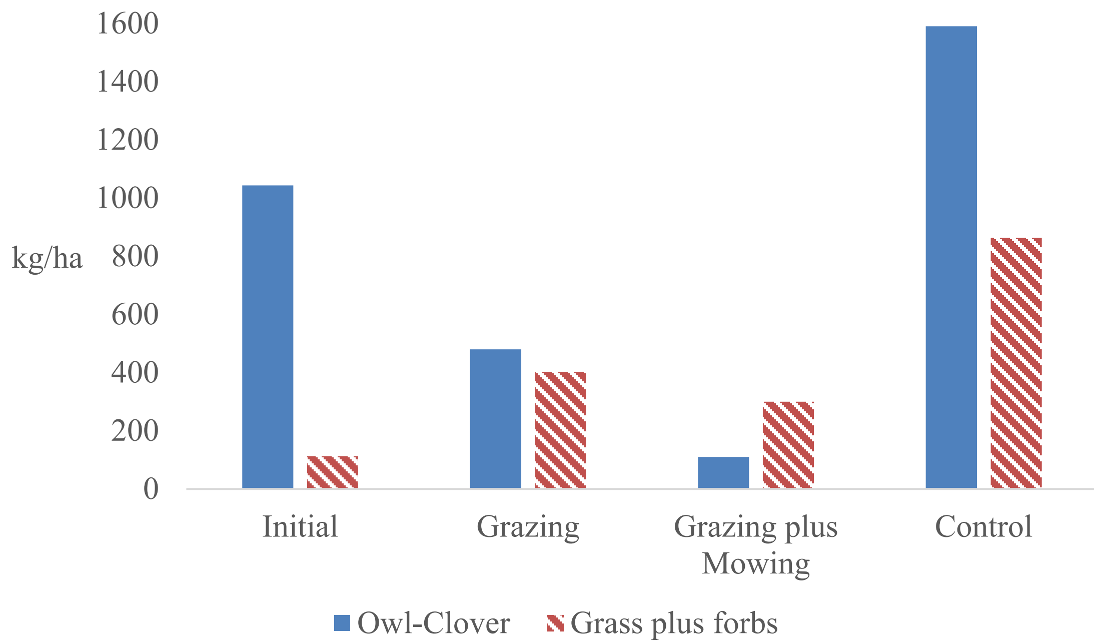

Figure 2. Mean Kilograms per ha for Bearded Owl-clover and grasses plus forbs measured initially using the grazing plus mowing transect and again at the end of the study for each treatment transect.

DISCUSSION

The interspecific interactions of Bearded Owl-clover with other plant species may have undesirable impacts on pasture and rangeland composition for livestock producers. Root parasites significantly reduce the dry mass of annual grasses, and it has been shown that grasses are the best hosts for parasite performance (Marvier, 1998). Marvier (1998) also showed large amounts of the root parasite *Triphysaria pusilla* (Benth) were supported by grasses, and even while suppressing grass growth, *Triphysaria pusilla* used disproportionately more water than its host species. Therefore, parasitic plants may harm neighboring plant species, other than the host, by acting as an indirect, aggressive competitor for soil water. Parasitic species compete for soil nutrients and water and may take these resources away from species to which they are not attached. Resource competition may lead to a change in the plant composition of the field; leading to a decrease in desirable hay and pasture species.

This mini-case study sought to examine the efficacy of cattle grazing and the combined effect of grazing and mowing in the management of undesired Bearded Owl-clover in pastures. Previous Canadian reports have observed Owl-clover populations grazed by non-migratory Canada Geese. A rapid increase in the geese population led to increased grazing of the Owl-clover, as well as trampling damage and loss of plant tissue (COSEWIC, 2011). Additionally, the Canada Geese population deposited an abundance of feces, which was observed to cause an increase in exotic annual grasses on the grazed Owl-clover sites (COSEWIC, 2011). COSEWIC 2011 reported that increases in invasive plant species impede the survival of Bearded Owl-clover through suppression and competition for space and resources. Light needed by Owl-clover to produce photosynthates is reduced by shrubs and medium to tall grasses, and the roots of invasive plants decrease the availability of moisture and nutrients to Owl-clover (COSEWIC, 2011).

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Similar trends were observed in Humboldt County during this opportunistic trial where Owl-clover only persisted in areas of short grasses where cattle, as well as an abundant population of Aleutian Geese, had been present for fall and winter grazing prior to the germination of Owl-clover. Directly adjacent to the Owl-clover transects was a California Department of Fish and Wildlife refuge with no active goose or livestock grazing, and zero Owl-clover plants were observed in the tall, decadent grasses.

Additionally, Canadian studies have reported the effects human disturbance and urban development have had on British Columbian Owl-clover populations. Trampling due to heavy pedestrian traffic in parks or outdoor recreation activities is a threat to Bearded Owl-clover populations and suitable habitat for the species. Populations in Canada located in public parks are regularly crushed before the species produce seeds and vernal seeps are compacted and eroded due to recreational activities (COSEWIC, 2011). Bearded Owl-clover is dependent upon winter seepage and altered hydrological regimes due to construction from urban development or soil compaction from grazing or pedestrian traffic may interrupt this process (COSEWIC, 2011). Disruptions to the hydrological patterns may lead to the decline of Bearded Owl-clover in those areas. Similarly, our site in Humboldt County was on poorly drained soils with common, short-term flooding and pooling.
Due to undesirable root parasitism and a noticeable loss of forage to a local beef producer, in this case study, the goal was to reduce Bearded Owl-clover on organic hay fields. After reading about the loss of desired Owl-clover to Canada Geese and human trampling, cattle were employed to accomplish similar trends on these private pasturelands. Initially, the cattle would not graze the Owl-clover for approximately five days after being introduced to the field and avoided areas with dense Owl-clover. However, once cattle began grazing the Owl-clover one week into the study, they utilized it as available forage and no negative side effects were observed in the cattle. By the end of the trial, the cattle even appeared to target the Owl-clover where available.

IMPLICATIONS

During this case study, no negative health impacts were observed on cattle grazing the Bearded Owl-clover. Little re-growth of the Owl-clover was seen after clipping or grazing, which suggests grazing may be an effective tool in reducing Owl-clover abundance. Ranchers wishing to decrease the Owl-clover population in their pastures, without the use of chemical treatments, may be able to utilize livestock grazing or mowing as alternative management tools. Managers interested in increasing Owl-clover blooms should consider moderate to heavy grazing regimes prior to late spring to reduce residual dry matter and provide ample short grass habitat suitable for Owl-clover establishment. If interested in increasing Owl-clover abundance, managers should consider reducing livestock grazing at the time of flowering and seed set to allow the plants to maintain photosynthetic materials and mature.

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Kerb Application Method, Timing & Rate Evaluation on Seeded Romaine Lettuce Trial: June 2020

Steve A. Fennimore and John S. Rachuy; University of California-Davis

Work was conducted to evaluate the performance of sequential applications of WaterMaxx and Kerb applied by chemigation through surface and buried drip tapes. Kerb was applied at 3.5 and 5 pints/A through surface and buried drip tapes at the second irrigation. Each Kerb treatment was preceded by an application of WaterMaxx at 4 pints/A through the respective drip tapes at the first irrigation. The standard was spray-applied Kerb at 3.5 and 5 pints/A over plots irrigated by buried drip tape. Two nontreated controls were included, with irrigation applied through surface and buried drip tapes. Sprinkler irrigation was not used in this trial at any time. The trial was arranged in a randomized complete block with 4 replicates. Data collected were weed control, crop injury estimates, and yield (Table 1). Data were subjected to analysis of variance and mean separation was performed using Fisher's LSD.

The surface spray-applied Kerb treatments controlled common purslane but did not control nettle leaf goosefoot. In general, none of the spray or drip applied Kerb treatments reduced total weed numbers (Table 2). No injury was observed in this trial (Table 3), and generally, the Romaine lettuce yields (crop stand, fresh weight, and size) were higher in the buried drip treatments than in the surface treatments (Table 4). NOTE: crop stand, weights, and size were lower in the non-treated controls due to direct competition from the ryegrass cover, sown to provide a visual indication of Kerb movement/spread over the bed top.

Table 1. Critical trial events and dates

Critical Event	Date / Information
Crop:	Romaine Lettuce
Planting Date:	5/15/20
Emergence Date:	5/25/20
Cultivar:	Abilene
Application Intervals:	
Pre-Emergence/At Planting Spray	5/16/20
WaterMaxx Drip Injection at 1st Irrigation	5/18/20
Kerb Drip Injection at 2nd Irrigation	5/20/20
Weed Counts:	6/8/20
Crop Injury:	6/8/20 (14-DPE*) 6/22/20 (28-DPE) 7/6/20 (42-DPE)
Yield (Fresh Weight):	7/24/20 (60-DPE)

*DPE = Days Post Emergence

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(continued from Page 21)

Table 2. Weed control (density)

Treatment	Rate (pt/A)	Timing	Applic Method	Drip Tape Location	Weed Density (No./2.8ft²)		
					Common Purslane	NettleLeaf Goosefoot	Total Weeds
WaterMaxx f.b. Kerb	4.0 3.5	At 1st Irrig At 2nd Irrig	Drip Inject	Buried	20.9 b	9.1	42.2
WaterMaxx f.b. Kerb	4.0 3.5	At 1st Irrig At 2nd Irrig	Drip Inject	Surface	20.5 bc	4.8	38.0
WaterMaxx f.b. Kerb	4.0 5.0	At 1st Irrig At 2nd Irrig	Drip Inject	Buried	21.5 b	6.8	41.8
WaterMaxx f.b. Kerb	4.0 5.0	At 1st Irrig At 2nd Irrig	Drip Inject	Surface	18.6 bc	2.1	30.6
Kerb	3.5	At Planting	Surf Spray	Buried	6.0 cd	18.3	38.5
Kerb	5.0	At Planting	Surf Spray	Buried	1.9 d	23.3	45.5
Non-Treated	0	---	---	Buried	30.6 ab	2.9	45.5
Non-Treated	0	---	---	Surface	38.8 a	7.1	56.1
LSD (P = .05)					14.7	14.4	29.3
Treatment Prob (F)					0.0009	0.0578	0.7868

Table 3. Romaine lettuce crop injury (0 =no injury, ≤2=safe, 10=dead)

Treatment	Rate (pt/A)	Timing	Applic Method	Drip Tape Location	Crop injury (0-10)		
					7/1/19 14-DPE	7/15/19 28-DPE	7/29/19 42-DPE
WaterMaxx f.b. Kerb	4.0 3.5	At 1st Irrig At 2nd Irrig	Drip Inject	Buried	0	0	0
WaterMaxx f.b. Kerb	4.0 3.5	At 1st Irrig At 2nd Irrig	Drip Inject	Surface	0	0	0
WaterMaxx f.b. Kerb	4.0 5.0	At 1st Irrig At 2nd Irrig	Drip Inject	Buried	0	0	0
WaterMaxx f.b. Kerb	4.0 5.0	At 1st Irrig At 2nd Irrig	Drip Inject	Surface	0	0	0
Kerb	3.5	At Planting	Surf Spray	Buried	0	0	0
Kerb	5.0	At Planting	Surf Spray	Buried	0	0	0
Non-Treated	0	---	---	Buried	0	0	0
Non-Treated	0	---	---	Surface	0	0	0
LSD (P = .05)					0.0	0.0	0.0
Treatment Prob (F)					1.000	1.000	1.000

(continued on Page 23)

(continued from Page 22)

Table 4. Romaine lettuce crop yield (stand, fresh weight, and size) at harvest.

Treatment	Rate (pt/A)	Timing	Application Method	Drip Tape Location	Stand (no./10' bed)	Fresh Weight (tons/A)	Size (g/plant)
WaterMaxx f.b. Kerb	4.0 3.5	At 1st Irrig At 2nd Irrig	Drip Inject	Buried	18.8	20.2	746
WaterMaxx f.b. Kerb	4.0 3.5	At 1st Irrig At 2nd Irrig	Drip Inject	Surface	20.0	23.9	825
WaterMaxx f.b. Kerb	4.0 5.0	At 1st Irrig At 2nd Irrig	Drip Inject	Buried	17.3	22.0	845
WaterMaxx f.b. Kerb	4.0 5.0	At 1st Irrig At 2nd Irrig	Drip Inject	Surface	20.3	26.0	886
Kerb	3.5	At Planting	Surf Spray	Buried	21.0	25.5	851
Kerb	5.0	At Planting	Surf Spray	Buried	20.3	22.4	754
Non-Treated	0	---	---	Buried	17.0	15.0	625
Non-Treated	0	---	---	Surface	19.5	18.6	665
LSD (P = .05)					4.3	8.3	190
Treatment Prob (F)					0.4629	0.1644	0.0902

Pre-plant Weed Management Followed by Mechanical or Chemical Control Improves Alfalfa Stand and Yield

Sarah Light, Agronomy Advisor, Sutter, Yuba, and Colusa Counties, UC Cooperative Extension

Background:
Good stand establishment is important for alfalfa production and can impact crop productivity for years. Weed competition during stand establishment may be irreversible because it impedes root growth, results in thinner alfalfa stands, and can lower forage quality. This project evaluated the efficacy of pre-plant weed control in alfalfa using mechanical cultivation or glyphosate spray to provide both organic and conventional growers with regionally relevant information about an integrated weed management tool for improved stand establishment.

(continued on Page 24)

(continued from Page 23)

Methods

Experimental Design:

Table 1. Experimental treatments			
Treatment number	Pre-plant treatment	In-season treatment	Herbicide rate(s)
1	None	None	N/A
2	Tillage	None	N/A
3	Glyphosate	None	3 pt/acre
4	None	Raptor	6 fl oz/acre
5	Tillage	Raptor	6 fl oz/acre
6	Glyphosate	Raptor	3 pt/acre + 6 fl oz/acre

Each treatment was replicated three times in a split-plot randomized complete block design. Main plots were pre-plant treatment (no pre-plant treatment, tillage, or Glyphosate) and sub-plots were in-season treatment (no treatment or Raptor application in-season). Sub-plots were not replicated within a block.

Weeds were germinated with winter rains. Pre-plant Glyphosate was sprayed on plots on 1/31/20 at a rate of 3 pints Glyphosate/acre. Mechanical cultivation (tillage treatments) were implemented on 2/11/20, once the soil was dry enough. This cultivation was very shallow, in the top few inches of the soil, to avoid bringing new weed seeds to the soil surface.

Alfalfa seed was flown on the field on 3/4/20 and the field was then ring-rolled to cover the seed and get good seed to soil contact. The field was then irrigated up a week later. In-season weeds were controlled with a tank mix of Raptor (imazamox ammonium salt) at 6 fl oz per acre and Buctril (bromoxynil) on 4/25/20.

Data Collected:

Baseline weed counts were taken on 1/29/20 from all plots before treatment implementation but after weed germination. Individual broadleaf weeds and grasses + sedges were counted in three random 20x20 cm quadrats per plot. Plants were counted on this date because weeds and alfalfa plants were small and percent cover would not have captured potential differences.

Weed counts were taken three times between planting and first cutting from all plots. In season weed counts were taken as percent cover, in which the area of the quadrat was broken up in percent covered with broadleaves, grasses + sedges, bare soil, and alfalfa. On 4/9/20 and 5/14/20 weed counts were taken in three random 20x20 cm quadrats per plot and on 6/8/20 percent cover was observed in 3 random square meter quadrats per plot (Table 2 and Table 3). The larger quadrat was used for percent cover on 6/8/20 because alfalfa and weeds were tall at this time and the meter by meter square allowed for a more accurate representation of each plot.

Plots were hand-harvested on 6/8/20 prior to the first cutting, which occurred on 6/10/20. Two square meter areas of each plot, which were representative of the larger plot, were cut. Yield biomass was separated into weeds and alfalfa, dried, weighed separately, and then converted up to a pounds dry matter/acre basis (Table 4).

(continued on Page 25)

(continued from Page 24)

Finally, on 6/23/20 following the first cutting, alfalfa stand counts were taken in all plots by counting the number of alfalfa plants in three 20x20 cm quadrats (Table 5).

Results:
Baseline weed count (1/29/20) collected before treatment implementation.
The average count for grasses + sedges for all plots was zero at this count. For broadleaves, there were no significant differences by treatment but there were significantly more weeds in the side of the field with no in-season control compared to the side where Raptor was applied in-season.

Weed counts:
4/9/20 (Data not shown):
Grasses + sedges: There were not many grasses or sedges in the field.
Broadleaves: There were significantly fewer broadleaves in the plots that had pre-plant weed control (glyphosate or tillage).
Alfalfa: Alfalfa plants were small at this counting date however, there were significant treatment differences with the pre-plant weed control treatments having more alfalfa than the control.

5/14/20 (Data not shown):
Grasses + sedges: There were not many grasses or sedges in the field.
Broadleaves: There were significantly fewer broadleaves in the plots that had pre-plant weed control (glyphosate or tillage) and in the plots that had Raptor applied in-season.
Alfalfa: There was significantly more alfalfa in the plots that had pre-plant weed control (glyphosate or tillage) and in the plots that had an in-season herbicide.

6/8/20 (at first cutting):
Grasses + sedges: There were not many grasses or sedges in the field and no significant differences by treatment. There were more grasses on the side of the field with no in-season herbicide application.

Broadleaves: There were significantly fewer broadleaves in the plots that had pre-plant weed control (Glyphosate or tillage) and in the plots that had Raptor applied in-season.

Table 2. Percent cover of broadleaves between treatments. Data reported as average percent per treatment ± standard error.

Treatment	*Raptor In-season*	*No In-season control*
No pre-plant treatment	94 ± 2.9	99 ± 1.3
Glyphosate pre-plant	5 ± 4.1	64 ± 10.6
Tillage pre-plant	4 ± .69	70 ± 6.8

Alfalfa: There was significantly more alfalfa in the plots that had pre-plant weed control (Glyphosate or tillage) and in the plots that had an in-season herbicide.

(continued on Page 26)

(continued from Page 25)

Table 3. Percent cover of alfalfa between treatments. Data reported as average percent per treatment ± standard error.		
Treatment	*Raptor In-season*	*No In-season control*
No pre-plant treatment	2 ± 1.2	0 ± 0.22
Glyphosate pre-plant	94 ± 3.6	29 ± 10.8
Tillage pre-plant	96 ± .70	23 ± 7.0

Alfalfa Yield: Yields are reported in pounds per acre as 100% dry weight. This yield data is only for the first cutting of the stand, not for the full first year of production. There were significant differences in alfalfa yield between pre-plant treatments and plots that had no pre-plant weed control. Both the Glyphosate and tillage pre-plant treatments increased yields. In addition, the Raptor spray significantly increased yields compared to plots without in-season control.

Table 4. Alfalfa dry matter yield. Data reported in lb/acre per treatment ± standard error.		
Treatment	*Raptor In-season*	*No In-season control*
No pre-plant treatment	53 ± 38.1	10 ± 2.4
Glyphosate pre-plant	3845 ± 163.6	1956 ± 332.3
Tillage pre-plant	3258 ± 233.4	1457 ± 388.9

Biomass was separated into alfalfa (above) and weeds after plots were hand-harvested. Then alfalfa and weeds were weighed separately by plot. There were significantly more weeds, by weight, in the side of the field that did not get the herbicide spray in-season compared to the side that did get an herbicide spray. However, within one side of the field (Raptor or not), there were no significant differences by pre-plant treatment. In other words, even though there was more alfalfa in the plots with pre-plant weed control, there were also more weeds. The photos below, taken at harvest show how heavy the weed pressure was even in plots with Glyphosate and tillage pre-plant that did not have in-season herbicide application.


Left: close up of a plot with Glyphosate pre-plant plus in-season Raptor.
Right: close up of a plot with Glyphosate pre-plant but no in-season herbicide.

(continued on Page 27)

(continued from Page 26)

Below are broad views of the same plots.

Alfalfa Stand After 1st cutting:
This is the number of alfalfa plants in a 20cm2 quadrant after first cutting. There were significant differences in the alfalfa stand after the first cutting. With regard to pre-plant treatments, both Glyphosate spray and tillage pre-plant significantly increased alfalfa stand compared to the plots with no pre-plant treatment.

When comparing plots with the same pre-plant treatments with or without in-season herbicide spray, plots that were tilled pre-plant did not have significantly different stand counts regardless of in-season herbicide treatment. However, within the plots that were sprayed with Glyphosate pre-plant, those that also were sprayed with Raptor in-season had significantly higher alfalfa stand counts than those without in-season control.

Table 5. Alfalfa plants/quadrat Data reported per treatment ± standard error.

Treatment	*Raptor In-season*	*No In-season control*
No pre-plant treatment	1 ± .22	0 ± .22
Glyphosate pre-plant	18 ± 1.7	12 ± 3.5
Tillage pre-plant	14 ± 2.0	11 ± 2.0

Example of count data taken after first cutting.

(continued on Page 28)

(continued from Page 27)

Project Summary:
The data shows that controlling weeds prior to planting, either with shallow tillage or an herbicide spray (Glyphosate) will reduce weed pressure, increase yields, and lead to a stronger alfalfa stand after first cutting. There were also differences between plots that got an in-season herbicide and those that did not. Yields were highest in plots that had both pre-plant weed control and an in-season herbicide. The plots with the highest stand counts after first cutting were also the plots that had both pre-plant and in-season weed control. However, the stand in the pre-plant treatment plots that did not have in-season herbicide application still had relatively high alfalfa stand counts after the first cutting. This means that the alfalfa stand may be more robust for future cuttings, even if weed pressure was high initially. As shown in the photos above, the alfalfa was robust in the understory of the canopy, even when broadleaf weeds were very large. By first cutting many broadleaf weeds had gone to flower so likely would not return after first cutting.

Ideally, both pre-plant and in-season weed control would be implemented to get the highest yields, quality, and ensure animal safety. However, growers (particularly organic) may be able to do pre-plant tillage to control weeds and establish a good alfalfa stand, have yield reduction and additional weed pressure leading up to first cutting, and then have a strong alfalfa stand for subsequent cuttings.

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Recent Weed Control Trials In Alfalfa

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Weeds are perennially persistent and problematic in cropping systems year after year. While a healthy stand of alfalfa can out-compete most weeds, winter annual weeds are often problematic in first cutting. Species like tumble mustard, tansy mustard, prickly lettuce, and shepherd's purse are common contaminants of hay fields. While these plants are not toxic, they detract from the quality of the hay and are visual deterrents for consumers. Winter annual grasses, such as cheatgrass and foxtails, are a different story with seed heads that can get lodged in the mucus membranes of livestock causing infections. Hay contaminated with these grasses is much less marketable. Furthermore, there are toxic weeds, such as fiddleneck, which can lead to the death of livestock if too much is consumed. But the real cost of weeds comes at the market, where weedy hay can be worth anywhere from $30-100 less per ton depending on the contaminant. This makes weed control an aspect that growers cannot afford to ignore.

(continued on Page 29)

(continued from Page 28)

Many growers of conventional alfalfa in the Intermountain Region often make applications of a residual herbicide combined with a burndown herbicide before the crop breaks dormancy in late winter. These applications can be an excellent way to control emerged weeds while creating a residual barrier for weeds yet to germinate. If made after dormancy is broken, unacceptable crop injury can occur. For the residual herbicides to be effective, they need to be incorporated into the soil profile by precipitation. Typically, in February and early March, there is adequate precipitation to activate these soil residual herbicides. Some years are too wet, with muddy fields preventing applications by ground rigs from occurring at all.

This past spring, we had a couple of field trials from which I wanted to share some data. The first was investigating an experimental herbicide (CNV2243) for dormant season applications. This experimental herbicide is thought to be similar (yet different) to metribuzin giving some control of small emerged weeds, but mainly having pre-emergent activity. We were looking at crop safety and weed control compared to metribuzin with and without the burndown herbicides Shark, Sharpen, and Gramoxone. Applications were made in late winter (early February) just as green buds were seen down in the crowns of the alfalfa. No precipitation fell until early March to incorporate the residual herbicides. It is not uncommon for growers to miss the late winter application window, so we also tested applications after the crop had broken dormancy on April 2nd.

In conversations with some pest control advisors, other valleys in the region never received any late winter precipitation to incorporate residual herbicides like metribuzin. Alfalfa had broken dormancy and they needed to apply a herbicide with more crop safety than a burndown product. While there are selective products like Pursuit and Raptor available to growers, they are not used as commonly outside of new seedings. Part of the reason for this is because of price, weed control spectrum, and potential for some injury. Some of the questions I was getting about Pursuit and Raptor I didn't have the answers to: Could you get adequate control with 3 oz. of Pursuit? Did adding AMS help with weed control but cause unacceptable crop injury? Did you need to add a grass killer like Select for adequate grass control? To help answer some of these questions, we put out an adjacent trial in the same field with a whole slew of postemergence treatments on April 2nd.

Both trials consisted of 10*20 ft. plots, replicated four times. Crop injury and weed control were evaluated at one-week increments following treatments and before harvest. Before harvest weed control data is shared in Table two. All treatments in both trials applied on April 2nd showed some crop injury, where any application of Shark or Gramoxone caused significant burn back of the crop. First cutting yields are reduced by the application of these contact burn down herbicides in previous research. All Pursuit and Raptor treatments also initially caused crop injury. While I cannot speak to the effect of the initial crop injury on yields in these two trials, all treatments outgrew any "visual" injury by the time of harvest (and could not be differentiated from the untreated check).

There were three weeds present at this field location: tumble mustard (*Sisymbrium altissimum*), prickly lettuce (*Lactuca serriola*), and cheatgrass (*Bromus tectorum*). Generally, dormant season treatments provided the best broadleaf weed control. Tumble mustard was controlled with most treatments in both studies. Prickly lettuce was more difficult to control. In the dormant trials, satisfactory control of prickly lettuce was only achieved when Gramoxone or Sharpen was included in the tank at the February application.

(continued on Page 30)

(continued from Page 29)

Photo One: Application of Raptor 6oz/acre. Tumble mustard adequately controlled, cheatgrass suppressed, and no control of prickly lettuce.

Only the tank mix with Gramoxone controlled prickly lettuce at the April application, with no control in any of the Pursuit or Raptor treatments. Cheatgrass was more difficult to target, and the best control was achieved in February applications that contained Select or Gramoxone in the tank. Cheatgrass was also controlled with 6oz Raptor + AMS, or a combination of Raptor + Select in April.

In terms of the questions we were trying to answer, the experimental herbicide seemed to have good crop safety in this trial, and offered good weed control as a tank mix partner but not as a stand-alone product. Pursuit at the 3 oz. rate was not very effective. Raptor had broader weed control activity and picked up cheatgrass when AMS was included. Shark and Sharpen looked pretty good on the broadleaf weeds but did not control the cheatgrass like Gramoxone. Generally, only a few dormant season treatments tested controlled all three weed species effectively. Adding Prowl to the tank did not increase control of any species for the April applications, as most of the weeds had already germinated. There are a lot of alternatives but Metribuzin + Gramoxone still offers some of the best broad-spectrum weed control out of options tested.

While often not emphasized in research reports, cost often drives what treatment a grower selects. Expensive treatments eat into the bottom line. However, an ineffective treatment will end up costing much more if the hay ends up weedy. It is a balance between treatment effectiveness and price. Tables Three and Four show the price of all treatments tested in these trials (herbicide only, not application cost). Some of the tank mix combinations cost significantly more than treatments that offered similar or even better weed control. One of the most cost-effective treatments was Metribuzin + Gramoxone in the dormant season trial. Raptor 6oz + AMS was one of the most cost-effective treatments tested in April, with the caveat of limited prickly lettuce control. Knowing your weed spectrum by field can help guide what combinations should be chosen.

(continued on Page 31)

(continued from Page 30)

Table 1. Weed control ratings before the alfalfa was harvested in the Dormant Season Trial. Letters indicate significant differences. Colors do not indicate differences but were only added to help visualize high and low ratings: green=good control and red=bad control. "2 in" indicates treatment was made after crop growth had occurred on April 2nd. All treatments with Shark or Sharpen included MSO 1% v/v, where all other treatments use NIS 0.25% v/v.

Dormant Trial: Percent Weed Control before Harvest						
	Tumble Mustard		Prickly Lettuce		Cheatgrass	
metribuzin (tricor 75df) .67 lb	91	a	83	ab	75	a
CNV2243 16 floz	35	bc	30	abc	14	bc
metribuzin (tricor 75df) .67 lb + gramoxone 1 qt	94	a	95	a	95	a
metribuzin (tricor 75df) .67lb + sharpen 2 oz	95	a	95	a	48	abc
metribuzin (tricor 75df) .67 lb + shark 2 oz	95	a	95	a	46	abc
CNV2243 16 floz + gramoxone 1 qt.	88	ab	91	a	88	a
CNV2243 16 fl oz + sharpen 2 oz	93	a	94	a	41	abc
CNV2243 16 fl oz + sharpen 2 oz + select 22 oz	93	a	95	a	94	a
CNV2243 16 oz + shark 2oz	89	ab	64	abc	3	c
2 in metribuzin (tricor 75df) .67 lb + gramoxone 2 qt	90	a	89	ab	43	abc
2 in metribuzin (tricor 75df) .67 lb + shark 2 oz	94	a	46	abc	5	c
2 in CNV2243 4L 16 fl oz + gramoxone 2 qt.	71	ab	90	a	63	ab
2 in CNV2243 4L 16 fl oz + Shark 2oz	71	ab	68	abc	10	bc
2 in CNV2243 16 fl oz + Shark 2 oz + Select 22 oz	68	ab	70	abc	64	ab
Control	0	c	0	c	0	c

(continued on Page 32)

(continued from Page 31)

Table 2. Weed control ratings before the crop was harvested in the adjacent post-emergence trial. Letters indicate significant differences. Colors do not indicate differences but were only added to help visualize high and low ratings: green=good control and red=bad control. The untreated control was not included in the statistical analysis because only two replications were evaluated. All treatments included NIS 0.25% v/v. AMS was added at 15lb/100 gallons of spray solution.

April Second Trial: Percent Weed Control before Harvest						
Treatment	Tumble Mustard		Prickley Lettuce		Cheatgrass	
Pursuit 3oz	78	a	20	a	17	c
Pursuit 6oz	70	a	23	a	35	bc
Raptor 6oz	95	a	10	a	69	abc
Pursuit 3oz + Select 16oz	94	a	5	a	66	abc
Pursuit 6oz + Select 16oz	71	a	15	a	51	abc
Raptor 6 oz + Select 16oz	95	a	20	a	85	ab
Pursuit 3oz + AMS	95	a	20	a	18	c
Raptor 6 oz + AMS	95	a	33	a	93	a
Pursuit 3oz + Select 16 oz + Prowl 2qt	76	a	28	a	65	abc
Pursuit 6oz + Prowl 2 qt. + AMS	95	a	35	a	64	abc
Raptor 6oz + Prowl 2 qt. + AMS	95	a	38	a	90	ab
untreated **	0		0		0	

Table 3. Cost of the chemicals (approximations based on quotes and online retailers, prices may vary).

Cost of Herbicides Alone	
Tricor 75 df 2/3 lb	$13.59
Gramoxone 1 qt.	$8.10
Sharpen 2 oz	$13.00
Shark 2 oz	$18.00
Select 16 oz	$19.25
Pursuit 3oz	$8.65
Pursuit 6oz	$17.29
Raptor 6oz	$24.28
Prowl 2 qt.	$33

(continued on Page 33)

(continued from Page 32)

Table 4. Cost of the tank mixes (approximations based on quotes and online retailers, prices may vary).

Cost of Tested Treatments	
Treatment	Cost
metribuzin (tricor 75df) .67 lb	$13.59
metribuzin (tricor 75df) .67 lb + gramoxone 1 qt	$21.69
metribuzin (tricor 75df) .67lb + sharpen 2 oz	$26.59
metribuzin (tricor 75df) .67 lb + shark 2 oz	$31.59
2 in metribuzin (tricor 75df) .67 lb + gramoxone 2 qt	$21.69
2 in metribuzin (tricor 75df) .67 lb + shark 2 oz	$31.59
Pursuit 3oz	$8.65
Pursuit 6oz	$17.29
Raptor 6oz	$24.28
Pursuit 3oz + Select 16oz	$27.90
Pursuit 6oz + Select 16oz	$36.54
Raptor 6 oz + Select 16oz	$43.53
Pursuit 3oz + AMS	$8.65
Raptor 6 oz + AMS	$24.28
Pursuit 3oz + Select 16 oz + Prowl 2qt	$60.90
Pursuit 6oz + Prowl 2 qt. + AMS	$41.65
Raptor 6oz + Prowl 2 qt. + AMS	$57.28

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