**Hop Research Council 2022 Research RFP**

June 16, 2021

**Project Title: Screening Post Emergence Herbicides for Basal Application in Hops**

**Project summary:** Despite the importance of herbicides in hop production in the USA, the active ingredients labeled for hop is restricted to nine sites-of-action. In 2020, four new active ingredients were identified as potentially suitable for hops based on crop tolerance, weed control spectrum, and reduced toxicity. The herbicides and respective sites-of-action WSSA group numbers were: tiafenacil (14), tolpyralate (27), halauxifen-methyl (4), and florpyrauxifen-benzyl (4). These compounds have known activity against crucial weed species that are problematic in hops, including, but not limited to: Canada thistle, field bindweed, Kochia, yellow nutsedge, and annual grasses. Based on the results of the 2020 and 2021 trials, we propose to continue testing tiafenacil and glufosinate as a spring pruning herbicide compared to carfetrazone. The findings of this study will support future registrations and help identify new use patterns for the active ingredients being evaluated for registration. Glufosinate is soon to be registered for hop. Results of 2020 and 2021 studies have attracted manufacturer support for a project clearance request to the IR-4 program.

**Proposed Duration: Three years (2020-2022); this document is for the third year (2022).**

**Project leader:**

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**Cooperators: Doug Weathers** Sodbuster Farms, Inc. Salem, OR.

**Funds requested:**

**2022:** 32,600 ($28,000 +$*4,600*) (revised to accommodate new objective and crop destruct charges)

**Other Funding Sources and Support:**

Washington Hops – We have requested an extension of this project scope into Washington State, although that request is not listed in this budget.

**Send Funds to:**

Agricultural Research Foundation, 1600 SW Western Blvd., Suite 320

Oregon State University, Corvallis, OR 97333.

Attn: Charlene Wilkinson; Phone (541) 737-3228 Email: [Charlene.Wilkinson@oregonstate.edu](mailto:Charlene.Wilkinson@oregonstate.edu)

**Project Title:** Screening Post Emergence Herbicides for Basal Application in Hops

*Statement of Problem:*

Chemical weed management options in hop yards are restricted to a small group of herbicides. Few of these herbicides are effective in controlling problematic weeds like field bindweed (*Convolvulus arvensis*), Canada thistle (*Cirsium arvense*), yellow nutsedge (*Cyperus esculentus*), and kochia (*Bassia scoparia*). Additional herbicide options with different sites-of-action in hops would contribute mightily to better herbicide resistance management (Norsworthy 2012). Herbicide-resistance is a problem in many weed species, including kochia, which is resistant to herbicide groups 2, 4, 5, and 10 in the western US (Heap 2020). Although less common, herbicide resistance has also been reported in perennial weeds like Canada thistle in Europe (Heap 2020). Environmental and human health concerns, as in the case of paraquat, can further limit herbicide availability. The identification of new active compounds would provide effective weed management options to hop growers while reducing the risk of selection for herbicide resistance.

**Relationship to Hop Research Council Research Priority:**

Weed Management Priority 4 - Management of Canada thistle, morning glory (a.k.a.; field bindweed), and kochia.

**Objectives:**

1. To evaluate hops response to herbicides tiafenacil, tolpyralate, and florpyrauxifen-benzyl.
2. To assess tiafenacil and glufosinate for spring pruning or crowning of hops.

**Justification and importance of proposed research:**

Management of kochia, Canada thistle, and field bindweed (a.k.a. morning glory) was identified as a research priority by hop growers (HRC, 2019). Management of these weed species in hops is challenging because of the restricted number of herbicides currently registered for hops. Seven active ingredients are used as preemergence herbicides and eight as post-emergence (Table 1). Those numbers are further reduced when considering the efficacy of weed control against the weeds listed here. Herbicides that have activity on these weeds, like glyphosate, cannot be applied to the hop row during the growing season, while 2,4-D use is restricted to the row middles. When considering these caveats, hop growers are often left with limited effective weed control options. Herbicides are the most commonly used method of weed control in hops, and herbicides will likely have a part to play in weed management programs even as non-chemical methods are introduced.

Consequently, the registration of new herbicides in hops will bring long-term benefits to the industry. One immediate service to hop growers will be an increase in the diversity of herbicide sites-of-action, an essential factor in herbicide resistance management (Norsworthy 2012). Herbicide resistance is a severe problem in multiple cropping systems. Although little has been documented in hops, resistant weeds are increasingly likely to become a problem. Herbicide-resistant populations of kochia are spreading across the US (Westra et al. 2019), and some are now documented in Western states, including resistance to herbicide groups 2, 4, 5, and 10 (Heap 2020). Herbicide resistance has also been reported in perennial weeds like Canada thistle (Heap 2020), although not in the US.

Three herbicide groups were identified for this project, WSSA group 4 - synthetic auxins, group 14 – PPO inhibitor, and group 27 – HPPD inhibiting herbicides. These groups were selected based on their limited use in hops, thus increasing site of action diversity, their potential for safe use in the crop, and the desired spectrum of controlled weeds, including the species of interest mentioned in this proposal. The active ingredients that were identified for evaluation on group 4 are florpyrauxifen-benzyl; on group 14, tiafenacil; and on group 27, tolpyralate.

Tiafenacil is a new protoporphyrinogen IX oxidase (PPO), or WSSA Group 14 herbicide. It is a post-emergence (POST) herbicide that controls grasses and broadleaves with reduced toxicity to humans. Tiafenacil is replacing paraquat in countries like Korea, where paraquat is banned (Park et al. 2018). Although group 14 herbicides are registered for hop (e.g., Aim (carfentrazone)), tiafenacil is active in grasses as POST, thus contributing to control of such tenacious weeds as Italian ryegrass. Tiafenacil was safely applied to 6-ft tall 'Meridian' and 'Mount Hood' hops in 2020, at a rate 4 times higher than the proposed label rate (50 g ai ha-1). Results are promising for 2021 in Cascade and Nugget variety. Tolpyralate is an herbicide in group 27, an HPPD inhibitor; this herbicide group is not currently labeled for hops. It is active against broadleaves, grasses, and Canada thistle. Tolpyralate was safe when applied to hops at 12- to 14-ft, or six- to eight weeks after training. Early applications did not injure to the crop when tolpyralate was applied in tank-mixture with tiafenacil. Florpyrauxifen-benzyl is a synthetic auxin with low volatility and low toxicity to humans. It is active against sedges, grasses, and broadleaves, including Canada thistle. Our results indicate that application of florpyrauxifen-benzyl to hop bines over 10ft tall is safer than to bines under 6ft. Additional field research is required to validate the 2020 and 2021 findings. Crop safety evaluation will support the registrations of the active ingredients identified as suitable for hops. This project will support the installation of a research hop yard for future weed management studies at Oregon State University Lewis Brown Research Farm and represents the initiation of a long-term effort to identify new herbicides suitable for hops in the United States. The proposed work will be conducted in collaboration with commercial growers in Oregon and other industry members.

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| Table 1. List of herbicides labeled in hops in Idaho, Oregon, and Washington in 2020. | | | | | | |
| Active Ingredient (WSSA group)1  [trade name] | Rate  (product/A) | Max use in 12 month period (product/A) | Application per season/ Reapplication  interval | Minimal Age (Month) | Replant  (Month) | PHI  (Day) |
| Preemergence | | | | | | |
| Dimethenamid (15)  [Outlook] | 0.56 to 1 lb ai  (12 to 21 oz) | 1 lb ai  (21 oz) | 1 / (NA) | 0 | 6 to 9 | 60 |
| Flumioxazin (14)  [Chateau SW] | 0.19 lb ai  (6 oz/A) | 0.19 lb ai  (6 oz/A) | - | - | 12 | 30 |
| Indaziflam (29)  [Alion] | 0.045 to 0.065 lb ai (3.5 to 5 fl oz) | 0.09 to 0.13 lb ai  (7 to 10 fl oz) | 2 /(6 months) | 12 | - | NA |
| Isoxaben (21)  [Trellis] | 0.5 to 1 lb ai  (16 – 32 fl oz) | 1 lb ai  (32 fl oz) | 2/- | - | - | - |
| Norflurazon (12)  [Solicam DF] | 2 to 4 lb ai  (2.5 to 5 lb) | 2 to 4 lb ai  (2.5 to 5 lb) | 1/ (NA) | 0 | 12 | 60 |
| Pendimethalin (3)  [Prowl H2O] | 1 to 4 lb ai  (1.1 to 4.2 qt) | 4 lb ai  (4.2 qt) | 2/(30 days) | 0 | 12 | 90 |
| Trifluralin (3)  [Treflan 4D] | 0.5 to 0.75 lb ai  [1 to 1.5 pt] | 0.5 to 0.75 lb ai  [1 to 1.5 pt] | 1/(NA) | 12 | 5 | NA |
| Postemergence | | | | | | |
| 2,4-D (4)  [various] | 0.48 lb ae  (1 pt) | 1.43 lb ae  (3 pt) | 3/(30 days) | NA | - | 28 |
| Glyphosate (10)  [various] | 0.38 to 3.68 lb ae  (see label) | 7.87 lb ae  (see label) | -/(14 days) | - | - | 14 |
| Capric + Caprylic Acid (17) [Supress EC] | 3 to 9% v/v  (varies by spray vol.) | N/A | N/A | N/A | N/A | 1 |
| Carfentrazone (14)  [Aim EC] | 0.03 lb ai  (2 fl oz) | 0.12 lb ai  (7.6 fl oz) | -/(14 days) | - | - | 7 |
| Clethodim (1)  [ various] | 0.068 to 0.12 lb ai (see label) | 0.5 lb ai  (see label) | -/(14 days) | - | - | 21 |
| Clopyralid (4)  [Stinger] | 0.125 to 0.25 lb ae (0.33 to 0.67 pt) | 0.25 lb ae  (0.67 pt) | 2/(21 days) | - | 12 | 30 |
| Paraquat (22)  [GramoxoneSL] | 0.5 lb ai(2 pt) | 1.5 lb ai  (6 pt) | 3/(-) | - | - | 14 |
| Pelargonic Acid (17)  [Scythe] | 3 to 10% v/v  (varies by spray vol.) | N/A | N/A | N/A | N/A | 1 |
| 1 WSSA group - Weed Science Society of America herbicide site of action group number.  (N/A) – not applicable, (-) no information available. | | | | | | |

**Procedures:**

1. To evaluate hops response to herbicides tiafenacil, tolpyralate, and florpyrauxifen.
2. To assess tiafenacil and glufosinate for spring pruning or crowning of hops.

Field studies will be conducted in commercial hop yards located in Salem and Independence, Oregon, in the Willamette Valley on sites no larger than 0.2 acres each. Evaluations will be made over two consecutive years at each location. All fields will be managed following the farm-standard practices. The experiment will be initiated when the crop reaches 6 to 8 ft tall, or no later than four weeks after training. Treatments will be applied by back-pack sprayer calibrated to deliver 20 GPA and equipped with drift-reduction nozzles generating coarse droplets. Applications will target the lower 2 ft of the plants. Each herbicide will be tested at three rates in two sequential applications: 1X - equivalent to the anticipated field rate, 2X - twice the field rate, and 4X - four times the field rate. To identify the crop tolerance, florpyrauxifen will be tested at multiple rates ranging from 3 to 42 fl oz at two growth stages. All treatments will include an ammonium sulfate source and methylated seed oil adjuvant.

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| Table 1. List of herbicide active ingredients, trade name, and proposed field rate for crop safety screening. | | |
| Treatment | Trade name | Field rate (product) |
| Florpyrauxifen-benzyl (4) | Loyant | 3 to 21 fl oz |
| Tiafenacil (14) | Reviton | 0.08 lb ai (3 fl oz) |
| Tolpyralate (27) | Shieldex | 0.026 lb ai (1.3 fl oz) |

The experimental unit (plot) will include three hop plants (six strings). Treatments will be arranged in a randomized complete block design with four replicates; they will be repeated in the following season. Evaluations will include visual estimation of bsal hop control in the treated zone (hop base), and above the treated area (crop injury), and crop height, internodal length, number of internodes, and length of primary and lateral branches. Leaf chlorophyll content will be measured using a non-destructive sample based on chlorophyll fluoresce ratio F735/F700 (Gitelson et al. 1999). Assessments will be made during the growing season at 1, 2, 4, 8, 10, 12, and 16 weeks after treatment. Plants will be harvested using a commercial picker (5p, HopsHarvester, Honeoye Falls, NY). Data will be submitted to ANOVA and means compared by Tukey's test. Funds for the establishment of a research hop yard to be built at OSUs Lewis Brown Farm are being requested this year. A plot of 1 acre is being prepared for a short-trellis yard installation at Lewis Brown farm.

1. To assess tiafenacil and glufosinate for spring pruning or crowning of hops.

Spring pruning or crowning is an essential production practice to maximize yield in hops and reduce powdery mildew (*Podosphaera macularis*) (Probst et al. 2016). The 2021 visual estimates of crop injury suggest that both tiafenacil and glufosinate are safe when applied in the spring over the top of cv. ‘Nugget’ hops. Crop height and yield are being monitored. A field study will be conducted at Lewis Brown Research Farm, Corvallis OR, in 2022 to evaluate glufosinate, tiafenacil and tiafenacil over two consecutive seasons. Crop desiccation and weed control will be assessed 2 and 4 weeks later. Hop shoot length and soil coverage will be recorded. Plants will be trained, and bine growth and plant development will be evaluated monthly. The experiment will be organized as a randomized complete block with four replicates and will be repeated in 2023.

**Outcomes:**

The findings of this project will identify new herbicidal active ingredients and sites-of-action to be labeled for use in hops. Additional herbicides will provide growers new tools to manage difficult to control weeds and reduce herbicide resistance selection pressure. In preparation for this project, the commercial, regulatory, and biology representatives from Corteva, BASF, and ISK, the registrants of the previously listed active ingredients, were consulted. ISK and BASF representatives visited research plots in 2021. The registrants are supportive of this work and will be involved throughout the research process to ensure the required data is generated for potential registration of compatible active ingredients. If and when appropriate, the IR-4 program will be involved, as the project PI is actively engaged in IR4 activities in the Pacific Northwest.

**Extension and Outreach activities:**

Research findings become the basis of new weed management recommendations to be disseminated through the PNW Weed Control Handbook. Information will be shared during the Hop Research Council and other events. However, the registration of a new herbicide is a long-term process, and the release of this information to the industry take place upon completion of any registrations.

**Time-frame**

The research for the second year of study will be conducted from March 2022 to October 2022. Data analysis and reporting will be available for the Hop Research Council by the end of the calendar year 2022.

**Anticipated work future years (2023)**

Results from HRC-funded work completed in 2021 guided the direction of this proposal. Our goal is to validate the initial findings during 2022. Evaluation of new use patterns of tiafenacil and glufosinate will be initiated in 2021, but it is necessary to conduct tolerance testing on the same plants over two seasons to validade crop tolerance. This validation work will take place in 2022. This project will expand and optimize the use of herbicides in hop production for difficult weed control, to manage weed herbicide resistance, and for hop plant crowning.

**References:**

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Westra, E. P., Nissen, S. J., Getts, T. J., Westra, P., & Gaines, T. A. (2019). The survey reveals frequency of multiple resistance to glyphosate and dicamba in kochia (*Bassia scoparia*). Weed Technology, 33(5), 664-672.

**Budget**

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| Budget: |  |
| Expenditure | Total amount requested (2022) |
| Salaries – Faculty research assistant | $ 9,167 |
| Employee benefits (76 %) | $ 6,967 |
| Undergraduate students ($17/h) | $ 6,000 |
| Travel ($0.56/mile) (1,785 miles) | $ 1,000 |
| USA hop and summer meeting | $ 1,900 |
| Materials ( product, field supplies, etc) | $ 794 |
| Other – new hop yard 0.2 AC | $ 2,172 |
| Crop destruct (pending on collaborator needs) | $ 4,600 (to be paid directly to collaborators) |
| Total | $ 32,600 (28,000 + 4,600) |

Budget Narrative

Salaries: Funding for 0.2 FTE equivalent for a Faculty research assistant. Annual salary was calculated at $46,150 plus $6,967 for other pay roll expenses (OPE) at 76%.( <https://research.oregonstate.edu/osraa/forms-and-rates/other-payroll-expense-ope-information-and-estimated-rates>)

Salary for 350 h of undergraduate students assistance is requested at $6,000 at $17/h including benefits. Students are assisting with hop planting, training, irrigation, and harvest.

Travel

Mileage – $1,000 is requested for travel. Multiple trips per season are made to each research location for approximate 1,785 miles at $0.56/mile.

USA Hops and summer meeting – we request $1,900 to attend to the HRC summer meeting and the USA hop meeting.

Materials. We request $794 to procure materials and supplies, including strings, sampling supplies, maintenance material, personnel protective gear, and consumables.

Others: A one acre hop yard is being installed at Lewis Brown farm with Cascade variety. We request $2,712 to cover for plot fees and additional materials needed like irrigation and poles.

Crop destruct: up to $4,600 in crop destruct charges to cover equivalent of 0.2 A in two locations. Estimated at $12/plant. This funding will not be paid the ARF, but rather directly to collaborator if needed.