The WHACK Experiment: Weed seed Harvest And Condense or Kill

On-Farm Harvest Weed Seed Control (HWSC) Protocol

Funding sources: NRCS On-farm CIG (Led by Muthu), Areawide (led by Mirsky)

Collaborators VA, LA, TX, DE, MD, IA, NC, IL, NE, MN, MO, WA, KS

Data Inventory Sheet

Data and Protocol is located in this Google Folder:
https://drive.google.com/drive/folders/1peQWtT2M7OTAq_9cVtF9F0KJtf-YOmrX?usp=sharing

Contacts for questions:

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iHSD: Jud Wheatley (jud@debruingroup.com.au; +61 407 313 335) Please allow 1 business day to respond as they are 12 time zones away)

Chaff Lining Kits: Tristan Freind (westozboilermaking@bigpond.com) Please allow 1 business day to respond as they are 12 time zones away)

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Part 1: Soybean/corn rotation

Objective: Determine the effects of cover crop, HWSC, and those combined for management of *Amaranthus* spp. and crop yield in a soybean/corn rotation.

Hypothesis: Both cover crops and HWSC will reduce *Amaranthus* spp. populations via seedbank depletion resulting in increased crop yield.

Treatments: Full 2x2 factorial of (+/- HWSC and +/- cover crop)

Cover crop species:

- Suggest cereal rye as the cover crop species prior to soybean
- Suggest cereal rye + legume prior to corn

    - Any legume selected based on local preference: could be hairy vetch, Austrian winter pea, clovers, etc.
- Final decision up to the participating grower
- Note: DO NOT PLANT cover crops in no-cover areas. Soil disturbance may influence the seedbank, which we are measuring.

HWSC tactic: implemented at <u>both</u> corn and soybean harvest

- Seed Impact Mill (Redekop SCU, iHSD, or Seed Terminator) (two farmers per PI)
    - Locations (State (number of fields)): VA (4), LA (4), DE (2), MD (4), IA (4), NC (4)
- Chaff lining (one farmer per PI)
    - Locations: TBD

Note on the iHSD: Unlike the Redekop SCU, the iHSD does not have ON/OFF capabilities. There are two options (1) using two combines (one with iHSD and one without) or (2) disconnecting the drive belt and removing chaff box doors. Note that if the mill is running, it must be covered to achieve a conventional (non-HWSC) harvest because if not the mill will have a powerful suction and some weeds will still be processed. *Make sure to note which option you used in the data sheet.*

Production practices: With the exceptions of the treatments and what is listed below, all production practices are up to the farmer. However, we need weeds to evaluate.

- No-till/min-till preferred
- No early POST herbicide applications (1 to 2 weeks after crop emergence)
- Apart from the treatments, all production practices need to be implemented uniformly across the entire experimental area.

Experimental Design: Randomized complete split-block design with cover crop/no cover being the main plot, and +/- HWSC as the split plot. 3 reps/blocks within a field (preferable) or use multiple fields to get 3 reps/blocks in total (each rep must include all 4 treatments). Final plot randomization is at the local researcher's discretion to allow flexibility with farmer's equipment, preferences, and field.

Field layout: Two total fields with soybean/corn rotation per cooperating farmer. Tracked for 4 years.

On-Farm CIG funding (seed impact mills): start with the CC planting in fall 2021 and cash crop in the 2022 field season, ending with final seedbank estimation, ideally in the spring of year 5).

- Field 1 starts after harvest in 2021, followed by cereal rye planting (in relevant plots) in fall 2021, and soybean planted into corn 2022
- Field 2 starts after 2021 harvest, with cereal rye + legume planting (in relevant plots) in fall 2021, and corn in 2022

Areawide funding (chaff lining): (starting with the CC planting in fall 2022 and cash crop in 2023 field season, ending with final seedbank estimation, ideally in the spring of year 5).

- Field 1 starts after harvest in 2022, followed by cereal rye planting (in relevant plots) in fall 2022, and soybean planted into soybean in 2023
- Field 2 starts after 2022 harvest, with cereal rye + legume planting (in relevant plots) in fall 2022, and corn in 2023

Initial Field Layout: A technician needs to be at the field when the farmer harvests prior to planting the cover crop. The farmer needs to set their RTK guidance during harvest so that the combine can follow the same path in subsequent harvests and plots do not move around. Randomization and final plot layout is up to each PI/farmer, provided it meets the criteria set forth below. **DO NOT RE-RANDOMIZE PLOTS** after initiation; each treatment will go on the same plots every year.

If a farmer does not have corn and soybean/grain headers that are the same width, we need to add alleys between plots to maintain 3 soybean/grain header widths. Cover crop planting equipment should be accounted for in the same manner; the total width of the cover crop planted area be at least 3 header widths.

Make a map for each field and enter this map and plot numbering into the Google Sheet for each field in the Shared Google Drive Data folder (https://drive.google.com/drive/folders/1zN7hwIvIF8Hq9XD0OZvYMUMLFR1pN7el?usp=share_link). Make sure to complete both sheets in the workbook: “Map” and “Plot treatment.”

Plot Size: Plots will be 3 grain/soybean header widths minimum (for example, 90 ft if the soybean header is 30 ft wide) by 300 ft long minimum; approximately 8 acres/field (7.5 acres plot area + 0.5 acres buffer). ***ALL data will be collected from the center soybean header width x 100 ft (subplot) of each plot.***

Example plot layout:

More examples here:HWSC field layout combine header sizes examples

Example field layout for corn/soybean rotation

	≥1,080 ft*											
	≥360 ft*											
	≥90 ft*	≥90 ft*	≥90 ft*	≥90 ft*								
300 ft minimum	+HWSC +CC	-HWSC +CC	+HWSC -CC	-HWSC -CC	-HWSC -CC	+HWSC -CC	+HWSC +CC	-HWSC +CC	-HWSC +CC	+HWSC +CC	-HWSC -CC	+HWSC -CC
	Rep/block 1**				Rep/block 2**				Rep/block 3**			

* Each plot needs to be at least 3 soybean/grain combine header widths wide. Given dimensions assume 30' header width.

** Preferably, each rep/block are in the same field. But multiple fields can be used to get 3 reps/blocks in total (each rep must include all 4 treatments). Final plot randomization is at the local researcher/farmer's discretion to allow flexibility with equipment, preferences, and available fields.

Permanent plot markers:

- GPS coordinates for each plot, around the corners. (Collected in data below)
- There needs to be some form or permanent plot or subplot markers so the plots do not move from one year to the next. These are options, but not the only options.:
    a. Buried radio frequency ID ball (1 in each corner of every per rep/block (need 12 per field)).
        i. Purchasing and device info here: RFID Buried Indicators
            1. $12.79 per RFID ball; come in packs of 30 for $384. Need one pack per farmer.
            2. 3M Dynatel detectors are about $2,400.
            3. Bury a ball at the front and back center of each plot, to align harvest passes from year to year (see these examples: HWSC field layout combine header sizes examples) deeper than field equipment will disturb.
    b. RTK-GPS also works, but is more technically challenging. *Recommended only for those who are comfortable with RTK-GPS.*
        i. Here is the most economical kit if you do not have one: https://store.emlid.com/product/reachrs-survey-kit/
    c. If you need to find other corners, measure and square from these permanent subplot markers.

Weeds: Amaranthus spp., other dominant weeds for the region (focus on key driver weeds)

Data:

Applies to both soybean and corn phases of rotation.

DATA COLLECTION WILL BE TAKEN FROM THE CENTER SOYBEAN HEADER WIDTH x 100 ft OF EACH PLOT or directly adjacent. Enter all data in the appropriate folder (your state > Farmer/crop rotation) here: https://drive.google.com/drive/folders/1C5Y3GYix-C_knm3_8iTy1OsycAawcz8g?usp=sharing

1. Soil seedbank quantification: Soil cores collected in spring 2022 (seed impact mills) or 2023 (chaff lining) at cover crop termination and the end of the project (ideally in the spring) to evaluate the seedbank (every 4 years).
    a. Sample every plot (minimum of 16 samples). Use a golf course cup cutter (4.3" wide) to a depth of 6 inches (Suggest: https://golfgriffin.com/product/magnum-golf-hole-cutter-includes-depth-gauge-style-scalloped-edge-outside-sharpened/). Bulk 4 cores together from each distance from the center (see below) of the plot into a single composite sample, thus yielding 4 composite samples/plot at the end. Sample from center soybean header width x 100 ft (length) of the plot.
        i. Structured random sampling:
            1. 4 random samples on the center line (including any chaff on top of the soil for chaff lining sites);
            2. 4 random samples 5 ft from center line,
            3. 4 random samples 10 ft from center line,
            4. 4 random samples 15 ft from center line,
            5. 4 random samples 20 ft from center line if your soybean header is 40 ft wide; otherwise do not collect this sample
        ii. Bulk the 4 cores within a distance category into a single composite and grow-out each composite separately so we can monitor any differences across the distance gradients.
    b. Exhaustive grow-out in the greenhouse, immediately after sample collection (do not put in freezer)
        i. Keep each plot and distance from the center line separate.
        ii. Count and pull weeds after 3 weeks. After 3 weeks, record total emergence by species (only count weeds that occur within the crops' growing season) for that period. Stir/mix the soil thoroughly. Repeat for a total of 3 emergence periods (9 weeks total). Enter data by species for each period.
        iii. Soil depth should be 1 inch or less (plan on two standard (~10" x 20") trays per subsample or 96 total trays).
2. GPS coordinates for each plot, around the corners.
3. Each season (all crops in the rotation)
    a. Production practices:
        i. Weather data: Data flow team will automate from weather API based on GPS coordinates of each site

1. Hourly gridded (~14km) with temp, modeled precip (from radar etc, not direct bucket tipping), radiation, evap, pressure, humidity (average), wind speed (high, low, average)

ii. Management practices and field history obtained from the farmer: dates, rates, row spacing, hybrids/varieties, physiological maturity date, killing frost date, HWSC implement, etc. for all field operations,

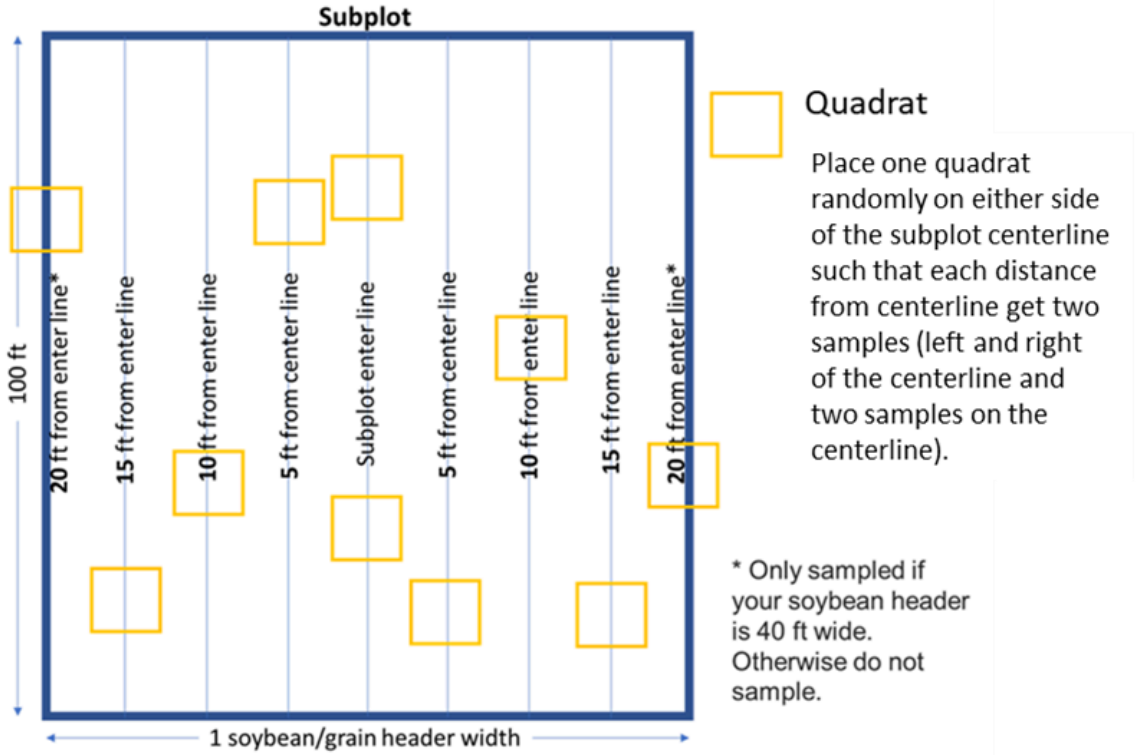
b. Cover crop and weed biomass (i.e. all *living* biomass) at burndown from 2 random 0.5 m^2 areas/plot. **This sampling includes both cover crop plots and winter fallow plots.** See Appendix A, Table 1 to determine the method of sampling the 0.5 m^2 area in broadcast or drilled cover crops. Quadrats should be within the center soybean header width by 100 ft subplot area of each plot. Collect above ground biomass, dry it, weigh it, and enter data.
   i. Visual estimate of cover crop composition (no legumes; >0 to 25% legumes; >25% legumes).
   ii. Visual estimate of the weed portion of above ground biomass (nearest 5 to 10%).

c. Weed emergence
   i. Monitored by counting weed species density for the three most prevalent species and remaining species grouped.
   ii. Find the 100 ft long by 1 header width subplot area and proceed with:
   iii. Structured random sampling: see map below
      1. If total weed pressure is low (i.e. <10 weed plants per m^2): at each distance from the centerline (0, 5, 10, 15, and 20* ft) count the number of plants in the following area:
         a. For corn and wide row soybean (≥20 inches), width of the counted area is equal to the crop row spacing. One crop row and only one crop
         b. row should be in the area. The length of the counted are in a is 100 ft (the length of the subplot).
         c. For soybean row spacing <20 inches the width of the counted area is 2 times the crop row spacing. Two crop rows and only two crop rows should be in the area.
         d. Note the area counted and enter this area in the data sheet.
      2. If total weed pressure is high (>10 weed plants per m^2) sample using 1 m^2 area quadrats within the subplot (center soybean header width by 100 ft of each plot)
         a. Sample each of the following: 2 random quadrat counts on the centerline (including any weeds in the chaff line for chaff lining sites); 1 random quadrat count on each side of centerline 5 ft from center line (2 total counts for this distance from center), 1 random quadrat count on each side of centerline 10 ft from center line (2 total counts for

this distance from center), 1 random quadrat count on each side of centerline 15 ft from center line (2 total counts for this distance from center), 1 random quadrat count on each side of centerline 20 ft from center line (2 total counts for this distance from center), *if your soybean header is 40 ft wide; otherwise do not collect this sample

b. Quadrats areas must be different from those used in part b above for cover crop sampling.
c. Quadrat dimension are adjusted to crop row spacing:
    i. For corn and wide row soybean (≥20 inches), quadrat width should equal the crop row spacing. Adjust the length so that the quadrat area is 1 m^2. One crop row, and only one crop row, should be in each quadrant.
    ii. Soybeans row spacing <20 inches: refer to Appendix A, Table 2 for quadrat dimensions.
d. Place quadrat on the line sampling line (see subplot map below), with the long edge parallel with the crop rows.
e. Note the area counted and enter this area in the data sheet.

iv. Count weed emergence before the first POST herbicide application (approximately 4 weeks after crop emergence) and at harvest.
    1. **DO NOT PULL WEEDS**; only counting.
v. If additional POST herbicides applications are made (which is discouraged), collect weed emergence data just prior to each application.



d. Crop stand count
    i. Just prior to the first POST herbicide application.
    ii. Count # of crop plants for 2 center rows in the plot by 30 ft long
e. TX, VA, MD, DE, IA, NC locations only will have fields mapped for weeds with the UAS protocol approximately 2 weeks prior to harvest: https://docs.google.com/document/d/1SwumenN0kPlqIfqz1JHkjn5XADrLmNoy/edit?usp=sharing&ouid=117189780247712661653&rtpof=true&sd=true
f. Within 1 week prior to corn and soybean harvest:
    i. Species-wise weed density (three most common species and remaining species grouped) will be measured in the structured randomly sampled 1 m^2 quadrats (see part c above). Quadrats areas must be different from those used in part b above for cover crop sampling, but can be the same or different than quadrats areas used in part c above. Refer to Appendix A, Table 2 for quadrat dimensions.
    ii. Weed biomass and seed production (three most common species but NOT remaining species) will be quantified by clipping weeds at the soil surface and hand-separated to quantify individual species, and oven-dried and weighed. Collect these data in 1, 0.5m^2 quadrats per distance (0, 5 ft, 10 ft, 15 ft, and 20 ft (if applicable) from the subplot center line, but just outside (in front or behind) of the subplot. Make sure these have at least one weed in the quadrat for each distance from centerline that had a

weed density greater than 0. Refer to Appendix A, Table 1 for quadrat dimensions.

1. Dry weed biomass (including seeds) to a constant weight and record that weight).
2. Weed seed will be separated and quantified. For each of the three most common species, thresh seed free from mother plants in each quadrat separately, clean seed as much as you can without losing any.
3. Count a 100 seed weight 5 times separately for each species and enter that number into the datasheet.
    a. Weight should include a proportional amount of trash if seed wasn't fully cleaned so that the 100 seed weight accurately reflects all the weighed material to calculate the full amount of seed.
4. Get a total seed weight (weight of seeds for the entire quadrat) and enter that into the data sheet.

g. Crop yield (yield map/monitor from combine).
    i. Record yield in bu/a (dry) and grain moisture (%).
    ~~ii. If your HWSC method is a seed impact mill, see Part 3 protocol (https://docs.google.com/document/d/1j0UjshTuke9E9aBTvefuzPAh3wRhkFKd/edit?usp=sharing&ouid=117189780247712661653&rtpof=true&sd=true) for additional chaff moisture and combine metric data to collect.~~

Appendix A

Drill spacing In inches	Drill Spacing in cm	# of Drill lines to Harvest	Cm long length per drill line to Harvest
Broadcast	Broadcast	none	100 cm x 50 cm
6”	15.24	7	46.87 cm
6.5”	16.51	6	50.48 cm
7”	17.78	6	46.87 cm
7.5”	19.05	6	43.75 cm
8”	20.32	5	49.22 cm
10”	25.4	4	49.21 cm
12”	30.48	4	41.01 cm

Table 1: How to harvest **0.5 meter square** area (of cover crop biomass or drilled biomass for example) depending upon various drill spacing. Selected drill lines should have representative gappy-ness, and do not necessarily need to be consecutive.

Formula for calculating drill line length to harvest of 0.5 m^2

0.5 m^2 = 5,000 cm^2

Length (cm) = 5,000 cm^2/ (Drill Line spacing (cm) x number of drill lines)

Drill spacing In inches	Drill Spacing in cm	Inter rows to sample	Cm long
6”	15.24	7	93.74 cm
6.5”	16.51	6	100.96 cm
7”	17.78	6	93.74 cm
7.5”	19.05	6	87.5 cm
8”	20.32	5	98.44 cm
10”	25.4	4	98.42 cm

12”	30.48	4	82.02 cm

Table 2: How to sample **1 meter square area** (of weed biomass or counts for example) depending upon various drill spacing. Areas sampled will be **between drill lines.**

Formula for calculating area to sample of 1 m^2

1 m^2 = 10,000 cm^2

Length (cm) = 10,000 cm^2/ (Drill line spacing (cm) x number of inter rows)