USDA-ARS | U.S. Wheat and Barley Scab Initiative

FY21 Performance Progress Report

Due date: July 26, 2022

Cover Page

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Fiscal Year:	2021
USDA-ARS Agreement ID:	59-0206-0-181
USDA-ARS Agreement Title:	Realtime Field Scab Assessment with Color and Spectral Imaging Systems on a Phenocart
FY20 USDA-ARS Award Amount:	$68,366
Recipient Organization:	University of Minnesota CFANS Bioproducts and Biosys Eng 207 BioAgEng, 1390 Eckles Ave. St. Paul, MN 55108-6005
DUNS Number:	555917996
EIN:	41 -6007513
Recipient Identifying Number or Account Number, if any:	CON000000086375
Project/Grant Period:	5/15/21 - 5/14/23
Reporting Period End Date:	5/14/2022

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
EC-HQ	Realtime Field Scab Assessment with Color and Spectral Imaging Systems on a Phenocart	$68,366
	FY21 Total ARS Award Amount	$68,366

I am submitting this report as an: ☒ Annual Report ☐ Final Report

I certify to the best of my knowledge and belief that this report is correct and complete for performance of activities for the purposes set forth in the award documents.

08/10/2022

Principal Investigator Signature — Date Report Submitted

‡ BAR-CP – Barley Coordinated Project
DUR-CP – Durum Coordinated Project
EC-HQ – Executive Committee-Headquarters
FST-R – Food Safety & Toxicology (Research)
FST-S – Food Safety & Toxicology (Service)
GDER – Gene Discovery & Engineering Resistance
HWW-CP – Hard Winter Wheat Coordinated Project
MGMT – FHB Management
MGMT-IM – FHB Management – Integrated Management Coordinated Project
PBG – Pathogen Biology & Genetics
TSCI – Transformational Science
VDHR – Variety Development & Uniform Nurseries
NWW –Northern Soft Winter Wheat Region
SPR – Spring Wheat Region
SWW – Southern Soft Red Winter Wheat Region

Project 1: Realtime Field Scab Assessment with Color and Spectral Imaging Systems on a Phenocart

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1. What are the major goals and objectives of the research project?

The **overall goal** of this project is to develop a real time high-throughput phenotyping method on a phenocart for field FHB assessment.

a) hasten and streamline image processing procedures to increase phenotyping efficiency;
b) enable real time field FHB assessments on the phenocart with on-board image computing;
c) verify deep learning models for more robust performance with crop field trials;
d) assess the feasibility of DON content detection in intact harvested wheat and barley seed by spectral imaging in comparison to GC-MS spectrometry.

2. What was accomplished under these goals or objectives? *(For each major goal/objective, address these three items below.)*

a) What were the major activities?

1) Developed a new series of phenotyping algorithms combining the detection of wheat spikes from complicated background with boundary boxes, and masking individual spikes. The detection algorithm for disease areas is under development.
2) The above mentioned algorithms were developed to be light-weight, so that the phenotyping platform will realize on-board image computing once the algorithm is integrated to the platform.
3) YoloV5-tiny deep learning model was trained and achieved 90% MAP (Mean Average Precision), which reduced the processing time more than 10 times compared to regular deep learning models, while maintaining the same detection accuracy.
4) Over 400 seed samples were scanned by an indoor hyperspectral imaging system. The data is being preprocessed and combined to the previous image dataset for a more robust DON detection model.

b) What were the significant results?

The new algorithm to be integrated to a phenotyping platform reduced the processing time more than 10 times compared to previously developed deep learning models while maintaining the same detection accuracy. It is ideal to be used for on-board wheat disease detection. It is versatile to be applied to either a phenocart or a smartphone applicatioin.

c) List key outcomes or other achievements.

1) Developed a new series of phenotyping algorithms combining the detection of wheat spikes from complicated background with boundary boxes and masking individual spikes. The new algorithm reduced the processing time more than 10 times compared to previously developed deep learning models while maintaining the same detection accuracy.
2) Published a peer-reviewed paper that reported the previous deep learning models (Wheat-Net and SpikeRetinaNet) that performed the best for wheat spike detection.

3) Other achievement: Developed a new quadruped (robot dog) platform specifically for side imaging in wheat/barley fields.

3. What opportunities for training and professional development has the project provided?

1) My visiting scholar Jiajing Zhang (currently a PhD student in robotics) was able to work on this project while she was in my lab and published our findings in a high impact peer-reviewed journal Frontiers in Plant Science.
2) It also fostered an international collaboration opportunity to work on a similar project using data resources from China. This collaborative work also resulted in a peer-reviewed journal paper with the report of a wheat spike detection model called SpikeRetinaNet. Two graduate students from my collaborator's group worked on this SpikeRetinaNet project.
3) Currently one MS student is actively working on the development of light weight deep learning models to be used for on-board FHB disease detection and achieved two third of our final goal. He will keep working on it for another year, with the goal of both full model development and a smart phone application development to increase the impact of this funded project.
4) Two MS students from the Minnesota Robotics Institute under my supervision are working on the robot dog platform as a more efficient, remotely controlled phenotyping platform with cameras to replace the previously developed phenocart. The goal is to achieve motorized phenotyping platform specifically for the wheat trial field with on-board processing capability.

4. How have the results been disseminated to communities of interest?

Findings and achievements have been published in peer-reviewed journals with high impact factor in the agriculture and food engineering domain. The new phenotyping platform (robot dog) will be shared in the 2022 FHB annual forum to the audience by a poster presentation and a live demo.

Publications, Conference Papers, and Presentations

Please include a listing of all your publications/presentations about your FHB work that were a result of funding from your FY21 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period** should be included.

Did you publish/submit or present anything during this award period?

☒ Yes, I've included the citation reference in listing(s) below.

☐ No, I have nothing to report.

Journal publications as a result of FY21 grant award

List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Include any peer-reviewed publication in the periodically published proceedings of a scientific society, a conference, or the like.

Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published [include DOI#]; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

C Wen, J Wu, H Chen, H Su, X Chen, Z Li, C Yang. 2022. Wheat Spike Detection and Counting in the Field Based on SpikeRetinaNet. Frontiers in Plant Science 13, https://doi.org/10.3389/fpls.2022.821717; acknowledgment of federal support - no.

Zhang J, Min A, Steffenson BJ, Su WH, Hirsch CD, Anderson J, Wei J, Ma Q, Yang C. 2022. Wheat-Net: An Automatic Dense Wheat Spike Segmentation Method Based on an Optimized Hybrid Task Cascade Model. 2022. Front Plant Sci. 13, 834938 . https://doi.org/10.3389/fpls.2022.834938, acknowledgment of federal support - yes.

Books or other non-periodical, one-time publications as a result of FY21 grant award

Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like.

Identify for each one-time publication: Author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (book, thesis or dissertation, other); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

Other publications, conference papers and presentations as a result of FY21 grant award

Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication.

David Aviles, Ce Yang, An Min, Corv Hirsch, Brian J. Steffenson. (2021). Development of a Lightweight Quadruped for Real-Time FHB Phenotyping Under Variable Field Conditions. P*roceedings of the 2021 National Fusarium Head Blight Forum*; Virtual. December 6-7, 2021. Retrieved from: https:// scabusa.org/forum/2021/2021NFHBForumProceedings.pdf