MISSISSIPPI SOYBEAN PROMOTION BOARD

Improving dryland soybean yield, profit and health of dominant soils across Mississippi

PROJECT NO: 62-2020

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Rationale/Justification:
Soybean is the most important crop in Mississippi in both acreage and value. In 2018, the Mississippi soybean harvested area was 2.19 million acres and had a total value of $1.104 billion, which surpasses other major crops combined. Because approximately 51% is grown under rainfed conditions, improving non-irrigated soybean yield and reducing production costs will be critical strategies for Mississippi producers to remain profitable. The majority of the annual rainfall in Mississippi occurs in the fallow season in December through April. During the soybean growing season (May to September), insufficient and erratic rain is a major limitation for dryland soybean production often resulting in low and inconsistent grain yield. Researchers have demonstrated that a 1% increase in soil organic matter (SOM) can improve soil water holding capacity by 20%. Thus, any management practice that increases SOM is likely to improve soil water holding capacity and water infiltration rate and conserve more rain water in the soil. The effectiveness of those practices to increase rainfed soybean yield and rain water use efficiency have received little attention and the financial returns and costs of each option are also unknown. Dryland grain yield is a function of the interactive effects of management practices with soil types, weather patterns, and many ecological and geographic variables. Field trials alone are often not sufficient to account for all such interacting variables and determine management options that are optimal for different soils under various growing environments. However, the use of field-calibrated crop simulation models, is considered a powerful tool for integrating the multitude of crop production variables and then selecting ideal management options with a given cropping-system scenario.

Objective 1: Determine cost-effective management practices to stabilize or improve dryland soybean yield and economic return in major soil types and growing environments across Mississippi. This research will determine the effectiveness of cover crop during the fallow season, broiler litter, municipal biosolids and biochar for improving soil health and increasing soil water infiltration, soil water holding capacity and organic matter, and minimizing runoff.

Cover crop and application of poultry litter and biosolids may help dryland grain production by making the soil fluffier (reducing bulk density), increasing organic matter, moisture holding capacity and infiltration rate, and improving aggregate stability and water use efficiency. In order to identify effective management practices for stabilizing or increasing dryland soybean yields, soil health and water use efficiency. We evaluated management of broiler litter, municipal biosolids, and cover crop during the fallow season across north central Mississippi.

1.1 Studies of Cover Crop and Brolier Litter at MSU Pontotoc Experiment Station in Pontotoc County

The Pontotoc field experiment was continued this year, in collaboration with Dr. Mark Shankle. It is an eight acre field which contains 2 types of soils, Atwood and Cascilla silt loam soils. In the fall of 2019, five different cover crop species were planted with three different fertilizer treatments. The five cover crops consisted of: wheat, cereal rye, vetch, mustard/cereal rye, and native vegetation. The three fertilizer treatments were poultry litter, standard pelletized fertilizer, and no fertilizer. These were combined to create 15 different plots, which were replicated four times. We sampled 45 of the 60 plots to measure initial conditions of soil physical properties, soil moisture and nutrients before the spring planting of the soybeans. Asgrow soybean (AG46×6) was planted on May 15, 2020 at the seeding rate of 128,000 seeds/ac on 30 inch rows. Cover crop and fertilizer treatments have been imposed according to plan. Soil and plan samples will be collected and processed for laboratory analysis. We have installed TDR soil moisture sensors (Acclima Inc.) coupled to a datalogger (Campbell Scientific Inc.) at depths of 0-6, 6-12, 12-18, 18-24 inches.

We measured leaf area index and chlorophyll content of soybean leaves twice this year. Leaf area index of soybean fertilized with PL was much higher than soybean treated with inorganic fertilizer (Table 1). It appears soybean was more healthy in the plots where cereal rye with mustard growed off soybean season. Soybean planted in Mid-May growed better than planted two weeks later. There was no much difference in the chlorophyll content of soybean among different treatments (Table 2). It indicated that nitrogen was not deficiency no matter what fertilizer was applied, as cover crops were planted out of soybean seasons. The results revealed that cover crop played a role in nutrient retention and supply.

Table 1. Leaf area index of soybean planted 1 (mid May) and planted 2 (early June), in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter).

Planted date		**CR**	**CRm**	**NV**	**VE**	**WH**	**Avg**
1	**Fert**	4.46	4.97	4.99	4.88	4.64	**4.79**
1	**None**	1.28	2.22	2.41	2.47	1.46	**1.97**
1	**PL**	5.56	6.96	5.63	5.86	6.16	**6.03**
	Avg	**3.76**	**4.72**	**4.34**	**4.40**	**4.09**	
2	**Fert**	2.96	3.17	2.99	3.09	2.30	**2.90**
2	**None**	1.93	2.11	2.04	1.97	1.74	**1.96**
2	**PL**	3.23	3.25	3.63	3.16	3.23	**3.30**
	Avg	**2.71**	**2.84**	**2.89**	**2.74**	**2.42**	

Table 2. The chlorophyll content of leaves of soybean planted 1 (mid May) and planted 2 (early June), in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter).

Plant date		**CR**	**CRm**	**NV**	**VE**	**WH**	**Avg**
1	**Fert**	43.4	41.2	41.9	43.0	41.9	**42.3**
1	**None**	38.2	39.0	40.5	39.7	37.2	**38.9**
1	**PL**	42.7	43.4	44.3	44.1	43.0	**43.5**
	Avg	**41.4**	**41.2**	**42.2**	**42.3**	**40.7**	
2	**Fert**	45.3	45.8	46.1	46.7	45.0	**45.8**
2	**None**	43.0	44.2	43.3	42.7	44.0	**43.4**
2	**PL**	45.9	45.7	46.4	45.9	45.6	**45.9**
	Avg	**44.7**	**45.2**	**45.2**	**45.1**	**44.9**	

Each plot was merchanically harvested on 10/9/2020, and the soybean grain yield was measured and calciulated based on measured grain gravimetric moisture ranging from 12-15% (Table 3). Averaged across all cover crop treatments, plots receiving poultry litter produced 4 bu/ac for early planted soybean and 2 bu/ac for late planted soybean. Late planted soyben produced silighly higher yield for the same fertilizer treatment. Averaged across all fertilizer treatments, there was no difference in grain yield for different cover crop plots. The highest yield was observed in plots planted cover crop NRCS mixture of mustard and rye, and vetch. Significant difference in yield was also found in the two cover crop plots receiving either inorganic or organic fertilizer, while plots treated with poultry litter produced higher yield. It appears that the fields planted NRCS mixture of mustard and rye, and vetch off soybean growing season and fertilized with poultry litter could produce higher grain yield.

Table 3. The grain yield (bushel/acre) of soybean planted 1 (mid May) and planted 2 (early June), in plots of different cover crops (CR: cereal rye; CRm: cereal rye with mustard; NV: native vegetation; VE: vetch; WH: wheat) off growing season, receiving Fert (inorganic fertilizer) and PL (poultry litter).

Plant date		**NV**	**CR**	**CRm**	**VE**	**WH**	**Avg**
1	**None**	34.5b	29.6b	36.2c	31.9c	29.3b	**32.3**
1	**Fert**	47.1a	48.6a	45.4b	43.5b	49.9a	**46.9**
1	**PL**	51.2a	48.5a	53.5a	52.5a	48.4a	**50.8**
	Avg	**44.3**	**42.2**	**45.0**	**42.6**	**42.5**	
2	**None**	33.7b	34.0b	34.7b	32.1b	33.2	**33.5**
2	**Fert**	50.9a	48.0a	49.7a	50.0a	48.2	**49.4**
2	**PL**	50.8a	51.5a	52.8a	52.6a	49.5	**51.4**
	Avg	**45.1**	**44.5**	**45.7**	**44.9**	**43.6**	

Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

1.2 Studies of Cover Crop, Chicken Litter and Biosolid at MSU North Farm in Oktibbeha County

This experiment was initiated in 2016 on a Marietta sandy loam and Leeper clay loam soils to determine the effects of timing and rates of broiler litter and bio-solid class A relative to inorganic fertilizer N on the soil water and rain water use efficiency and grain yield of soybean in the presence or absence of winter cover crop. Experimental design was a split-split plot replicated three times. The main plots were cover crop vs. no cover crop residue, the split plots were fall vs. spring application and the split-split plot included bio-solid, broiler litter, inorganic fertilizer and a control (**CK**, unfertilized). Biosolid was applied at the rate of 3 tons/acre in both fall (**Fall Agro BS**) and spring (**Agro BS**) from 2016-2019, broiler litter at the rate of 3 tons/acre was applied only in spring 2017 (**Agro Litter**). Winter cover crop was planted in November each year and chemically killed using Roundup on April next year. Pelleted biosolid and poultry litter at agronomic rate of 6 ton acre^{-1} and inorganic N fertilizer at the rate of 196 Ibs N acre^{-1} were applied to corn in 2019 growing season in the presence and absence of cover crop residue.
Cover crop cereal rye was planted on 10 Oct, 2019 and chemically terminated on 15 April, 2020. Soybean group 4 variety Asgrow (AG4835) was planted on 5 May, 2020 at the seeding rate of 130,000 plant per acre with 38" row spacing. Nothing was applied to any treatment to determine the impact of the residual nutrients on soybean production. Soybean was defoliated on 16 September 2020 and harvested for grain on October 8, 2020. Grain samples were collected during harvest for each plot and will be analyzed for grain nutrient concentration and grain protein. Soybean was grown in 2017 and 2020 under residual nutrient from broiler litter and biosolid applied to corn (2016), cotton (2018) and corn (2019). At harvest on 10/5/2020, the two middle rows were harvested using two rows combine. Total of 36 plots were harvested.
In 2020, soybean was grown in residual plots. No fertilizer, biosolid or poultry litter was applied. The fertilizer treatments mentioned as below and in table 4 represent the treatments from 2016 to 2019. Soybean in the plots treated with high biosolid had 2 bu/acre more grain yield under cover crop than no cover crop. The plots even produced 3.8 and 1.5 bu/acre more in the absence of cover crop. No difference was observed between cover crop and without cover crop for the inorganic fertilizer treatment. It is not surprising if soybean grain yield be greater in the absence of cover crop than in the presence of cover crop residues. Because major part of residual nutrient, particularly N, was utilized by cover crop. The cover crop was winter wheat in which the residue decomposes very slow and nutrients most likely released late in the season and they might not be available to soybean plants at peak demand (flowering and pod forming growth stages, mainly in June and) during growing season. In this case the presence of cover crop is disadvantage agronomically.

Table 4. The grain yield (bushel/acre) of soybean with and without cover crop cereal rye, soybean growth relied on residual nutrients in plots of different fertilizer treatments implemented from 2016 to 2019.

Plant date	**CK**	**High BS**	**Agro BS**	**Agro Litter**	**Agro Fert**	**Fall Agro BS**	**Avg**
No cover	71.11	64.08	67.62	62.98	67.98	65.88	**66.61**
Cover	67.21	66.39	63.73	61.31	67.11	62.40	**64.69**

Objective 2: Apply agroecosystem models, in conjunction with field trials in Objective 1, to determine optimal management options for consistent dryland soybean yield across typical Mississippi weather conditions and in each of 16 dominant soil types based on 100-year daily weather records and on predicted daily weather in future 50 years.

RZWQM2 is being applied to determine the effect of wheat winter cover crop (WCC) on net nitrogen (N) mineralization and nitrate leaching in a 80-yr (1938 to 2017) corn-soybean rotation and soil water balance and dynamic under future 60-yr (2020-2079) climate conditions, in Mississippi Blackland Prairie. Based on the annual soil N dynamics, the model also estimate nitrate losses as deep percolation during wheat, corn, and soybean growth periods between WCC and winter fallow (WF) under different seasonal rainfall patterns, 'wet', 'normal', and 'dry' years. The goal is to determine whether or not planting a wheat cover crop in a corn-soybean cropping system is an effective approach to mitigate future climate extremes for increasing system water and nitrogen use efficiency.

80-yr of RZWQM2-simulation demonstrated that, compared to winter fallow system, planting winter wheat cover crop (CC) into a corn-soybean system increased annual N mineralization by 15% (19 Ibs N ac^{-1}), improved annual denitrification by 9% (1 Ibs N ac^{-1}), and reduced annual nitrate loss to deep percolation by 20% (15 Ibs N ac^{-1}). On the basis of a full year simulation, the wheat winter CC grown from early October to early April led to a 24% reduction in nitrate-N leaching (14 Ibs N ac^{-1}). The efficacy of wheat winter CC in reducing nitrate leaching was better in wetter than dry winter months. Incorporating wheat winter CC into corn-soybean rotation is effective for promoting nitrogen mineralization and reducing nitrate loads to drainage deep percolation in humid regions.

Objective 3: Conduct economic analysis using results of field trials (Objective 1) and simulation studies (Objective 2) to compare the cost and return of using soil organic amendments or/and cover crop in comparison with conventional management practices. The goal is to help non-irrigated soybean growers in different Mississippi environments determine the long-term profit-maximizing management practices for a soil type, topography, precipitation pattern, and other climate condition found on their farm.

The RZWQM2 simulated data will be incorporated with the soybean price and cover crop cost information to build a soybean profit function, and solve for the profitability maximization problem using mathematic programming techniques under various constraints (budget, water capacity, *etc*.). The final output will be an interactive budget table, giving the specific cover crop recommendations under different soils, water costs, and soybean sale prices. The soybean profit functions and the budget table can provide guidelines for producers to determine the economically cover crop and nutrients management options under various weather and market conditions. Those results allow the producers to accurately weigh returns from increased yields against potential management costs on their specific fields. That provides a tool to more precisely manage their farm and improve profitability in soybean production.

End Products in 2020:

Presentations and Published Abstracts:

(1) **Feng, G.** and D. Reginelli. 2020. Improving dryland soybean yield, water use efficiency, and health of dominant soils across Mississippi. The Annual Mississippi Water Resources Conference, Jackson, MS. https://www.wrri.msstate.edu/abstract.php?y=2020

(2) **Feng, G.**, H. Tewelde, A. Adeli, and D. Reginelli. 2020. Invited oral presentation: advances in 4Rs research on manure application to row crops for improving soil health in the Southeastern USA. International symposium entitled "Emerging Needs in 4Rs Nutrients Research" at the ASA-SSSA-CSSA virtual international meeting, Nov. 9-13, 2019.

(3) *Chang, T.*, V. Paul, **G. Feng**, A. Adeli, and J. Brooks. 2020. Determining a minimum data set for assessing soil health in Mississippi. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(4) Paul, V., T. Chang, **G. Feng**, and A. Adeli. 2020. Soil health assessment methods: a comparative study. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(5) *Zhang, Y.* **G. Feng**, G. Bi, and S. Yu. 2020. Effects of cover crops on soil physical health in South American organic farming systems. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(6) *Li, Y.* **G. Feng**, and H. Tewolde. 2020. Measuring and assessing soil physical health in long-term boiler ash application: an on-field study in Mississippi State. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(7) *Gao, F*. **G. Feng**. 2020. Impact of climate change and cropping systems on groundwater recharge in a humid region. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(8) *Li, Y.* **G. Feng**, and H. Tewolde. 2020. Long-term effects of biochar on fertility, physical and hydrological properties and corn yield of dissimilar soils in Mississippi state. Agronomy Abstract. ASA, CSSA & SSSA Virtual International Annual Meeting, Nov. 9-13, 2020.

(9) Chang, T., V. Paul, and **G. Feng**. 2020. Methods for assessing the impact of soil amendments and cover crops on soil health. The Annual Mississippi Water Resources Conference, Jackson, MS.

(10) Han, Y., **G. Feng**, Y. Ouyang, W. Jin, Z. Liu, and J. Jenkins. 2020. The influence of agricultural water management practices on groundwater table and recharging in Big Sunflower Watershed. The Annual Mississippi Water Resources Conference, Jackson, MS.

(11) Heng, T., **G. Feng**, D. Reginelli, X. He, F. Li, and J. Jenkins. 2020. Impact of conventional and water-saving irrigation schemes on soybean yield in Big Sunflower River Watershed. The Annual Mississippi Water Resources Conference, Jackson, MS.

(12) Zhang, Y., **G. Feng**, G. Bi, and S. Yu. 2020. Impact of long-term organic fertilizer on soil physical health in the Southern United States. The Annual Mississippi Water Resources Conference, Jackson, MS.

Publications and Manuscripts:

(1) *Yang, W.*, **Feng**, **G.**, Read, J., Ouyang, Y., and Li, P. 2020. Impact of cover crop on corn-soybean productivity and soil water dynamics under different seasonal rainfall patterns. *Agronomy Journal*, 112: 1-15. DOI: 10.1002/agj2.20110. Quantified the role, capacity and conditions of cover crop in improving soil health and water use efficiency. This innovative research was featured in *CSA News* magazine and on social media of the tri-societies, 2020. https://acsess.onlinelibrary.wiley.com/doi/10.1002/csan.20078

(2) **Feng, G.**, H. Tewolde, B. Zhang, N. Buehring, A. Adeli. 2020. Soil physical and hydrological properties as affected by a five-year history of broiler litter applied to a cotton-corn-soybean rotation system. *Soil Science Society of American Journal*. https://doi.org/10.1002/saj2.20224. Determined beneficial duration and effects of broiler litter on soil properties and soybean production. The work was reported in MSU Extension publication, the newsletter (goes by 1600 emails) of Mississippi Crop Situation and posted on the blog and tweets with 2500 followers,: Effect of Poultry Litter Applications on Soil Physical Properties.

(3) *Li, Y.*, H. Tewolde, D. Miles, J. Munyon, J. Brooks, **G. Feng**, M. Yang, F. Zhang. 2020. Decomposition of poultry litter organic matter may be slowed by co-applied industrial and agricultural byproducts. *Journal of Environmental Quality*. doi: 10.1002/jeq2.20189.

(4) *Li, Y.*, **G. Feng**, H. Tewolde, F. Zhang, and M. Yang. 2020. Soil aggregation and water holding capacity of soil amended with agro-industrial byproducts and poultry litter. *Journal of Soils and Sediments*, 1-9. 10.1007/s11368-020-02837-3.

(5) *Li, X.*, G. **Feng**, H. Tewolde, A. Adeli, and J. Jenkins. 2020. Effect of improved soil organic matter using poultry litter on field water holding capacity of silt loam soils. *Land Degradation and Development* (internal review).

(6) **Feng, G**., and R. Sui. 2020. Evaluation and calibration of soil moisture sensors in undisturbed soils. *Transactions of the ASABE*. 2020. 62(2): 1-11. https://doi.org/10.13031/trans.13428

(7) *Yang, W.*, **G. Feng**, A. Adeli, H. Tewolde, and Z. Qu. 2020. Simulation of long-term impact of wheat cover crop on soil nitrogen losses from corn-soybean rotation in southeastern United. *Journal of Cleaner Production*, https://doi.org/10.1016/j.jclepro.2020.124255

(8) *Chang, T.*, **G. Feng**, V. Paul, A. Adeli, and J. Brooks. 2020. Soil health assessment methods: progress, application and comparison. *Advances in Agronomy*. (submitted).

(9) *Li, Y.*, **G. Feng,** H. Tewolde, M. Yang, and F. Zhang. 2020. Different years of boiler ash application to commercial no-tilled farm fields for improving soil physical health. *Journal of Soil and Sediments* (accepted).

(10) *Chang, T.*, **G. Feng**, V. Paul, A. Adeli, and J. Brooks. 2020. Determining a minimum data set for assessing soil health in Mississippi. *Soil & Till Res.* (internal review).