MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT NO 21-2016 (Year 4)
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TITLE: Response of and net profit from genetically enhanced and conventional soybean varieties to fertilizer recommendations from soil testing laboratories on low nutrient status soils in Mississippi produced with dry-land and irrigated environments.

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BACKGROUND AND OBJECTIVES

Soybeans are an increasingly important crop in Mississippi agriculture. In 2010, soybean was 3rd in dollar value in Mississippi behind forestry and poultry, with a value of $846 million. In 2017, there was an estimated 2.25 million acres of soybean planted in Mississippi, which is up 210,000 acres from 2016.

Research indicates that new varieties have provided a gradual genetic yield increase of 22 to 26 lb/ac over time. A study conducted in 2009 with 18 southern soybean cultivars to validate the yield difference between old vs. new cultivars suggests that 79% of the yield increase can be attributed to increased seed production compared to 21% for an increase in seed size.

As yield of soybean increases, so does removal of soil nutrients. If the level of potassium (K) in the soil becomes limited, soybean plants will begin to develop yellowing leaves beginning at the leaf margins, moving inward on the leaf. Deficiency symptoms will usually appear first on older leaves lower on the plant. In severe cases nearly the entire plant will show these symptoms of deficiency. Soybean that are deficient will have reduced yields compared to soybeans that have been supplemented with K_2O fertilizer. It has also been determined that seed produced from K-deficient soybean have lower oil and K concentrations. Maintaining a sufficient level of K to the soybean plant may become even more important in the future as yield continues to increase with the selection of desirable lines with high and stable yields, further advancement of resistance to nematode pests, and other improved genetic gains.

Most growers rely on soil test recommendations to manage soil nutrients. However, long-term studies conducted from 1994 to 2005 that evaluated phosphorous (P) and K removal from an unfertilized soil reveals that levels removed may be somewhat complex with regard to soil test values. This report indicates a good relationship between P removal and soil test P (STP), but a poor relationship between K removal and soil test K (STK) decreasing trends. Explanations for this response were that the influence of environmental conditions on short-term nutrient recycling from crop residue and interaction with other nutrients could have a higher impact on STK levels vs.STP levels. Therefore, recommendations derived from STK levels (especially in low to very low ranges) need to be validated to confirm that appropriate rates are applied to maximize yield and profit, while making sure rates do not reach levels that could be subjected to “luxury consumption” by the plant.

Over the past decade, soybean yield level goals have been promoted to maximize yield potential and some laboratories recommend specific “moving target” fertilizer rates based on higher yield expectations. Therefore, research will be designed to validate fertilizer recommendations on K-deficient soil from several soil testing laboratories on new vs. old cultivars produced in no-tillage or tilled environments and dryland vs. irrigated management practices. This study will use these factors to create several scenarios specific to the production practices that soil test laboratories use to tailor fertilizer rate recommendations.

Current research conducted at the Pontotoc Branch Experiment Station indicates recommended rates of K from both public and private sector laboratories improve soybean yield grown on K-deficient soil. However, there was a wide gap in profit margin to the grower between the recommendations. This new proposed project will address additional factors such as yield level goals with new and old cultivars produced with dryland and irrigated conditions. Inclusion of these additional factors should "narrow the gap" in the profit margin between different laboratory recommendations and validate the need (or not) for performance-driven levels of fertilizer inputs.

Objective(s)

Objective 1. Validate current soil testing recommendations from several soil testing facilities for potassium (plus other nutrients) for soybean produced on soil low in potassium under dry-land and irrigated environments. *Recommendations vary among laboratories with some labs using yield goal levels, while others promote a single use rate. This research will provide insight to growers for making fertilizer management decisions based on the lab they prefer to utilize.*

Objective 2. Identify optimal K_2O fertilizer rate for new high yielding soybean compared to a non-genetically enhanced, conventionally-bred variety in dryland and irrigated environments. *In addition to rate validation and optimization, these results could advance variable rate technologies through adjustments to equations utilized in field prescription recommendations in the future; i.e. rate based on specific soil level, not index range.*

Objective 3. Determine the economic benefits of each fertilizer rate recommended by several soil testing laboratories in Mississippi and adjacent states. *Preliminary results from previous research indicate that recommendations from soil test laboratories are different from each other. Higher recommended fertilizer rates may or may not maximize yield and can violate the "law of diminishing returns" for crop revenue.*

REPORT OF PROGRESS/ACTIVITY

Materials and Methods

A research study was conducted from 2012 to 2014 on a Falkner silt loam (Fine-silty, siliceous, thermic Aquic Paleudults) in the Hill region of Mississippi at the Pontotoc Ridge-Flatwoods Branch Experiment Station near Pontotoc, MS. This location was selected because of limited soil nutrient levels in order to promote the highest potential for plant response to all fertilizer treatments. This area had been in row crop production for many years prior to the establishment of this study.

The experimental design was a randomized complete block with 4 replications in a no-tillage, dryland and irrigated environments. Plot size was 10 x 40 ft containing four 30-inch-wide rows. In the spring of 2012, a representative soil sample was collected from the study area and submitted to the Mississippi State University Extension Service (MSU-ES) Soil Testing Laboratory (public lab) and a private soil testing laboratory (private lab). The soil sample was air-dried, ground, and divided into sub-samples. The divided samples were analyzed by MSU-ES and the private lab. In subsequent years a soil sample was collected from each fertility treatment, prepared for testing, and a sub-sample was sent to the laboratories for analysis.

Soil extraction methods used were Lancaster and Mehlich 3. Treatments include soil test recommendations from each laboratory with the private lab having recommendations for a low and high yield goal. Additional treatments included a potassium fertilizer rate regime that reached beyond the recommended rates at the initiation of the study.

The potassium fertilizer rate regime ranged from 0 to 150 lb K_2O/acre. Fertilizer sources were muriate of potash (60% K_2O), triple superphosphate (46% P_2O_5), elemental sulfur (90% S), magnesium sulfate (9.8% Mg & 12.9% S), copper sulfate (25% Cu), zinc sulfate (35.5% Zn), solubor (17.5% B), and manganese sulfate (31% Mn). All fertilizer treatments were made to two soybean varieties, Hutcheson (older conventional variety) and AG 5332 (newer RR2Y variety). Soybeans were planted on May 23, 2012, June 4, 2013, and June 3, 2014. Hand-application of fertilizer treatments was made on May 23, 2012, June 5, 2013, and June 4, 2014. Soybean leaf samples were collected on July 29, 2013, and July 30, 2014 at the R1-R2 growth stage for leaf tissue nutrient analysis.

The irrigated portion of the trial was irrigated 3, 9, and 5 times in 2012, 2013, and 2014, respectively. Irrigation was made based on the University of Arkansas Irrigation Scheduler computer program. The two center rows of each plot were harvested on October 24, 2012, October 25, 2013, and October 21, 2014 with an Almaco PMC 20 combine equipped with a HarvestMaster weigh system, which recorded plot weight and seed moisture. A seed sample was collected from each plot for conducting seed nutrient analysis. Yields were adjusted to 13% seed moisture content for statistical analyses. An economic assessment was conducted to compare net profit based on yield and cost of each fertilizer treatment. Prices for fertilizer sources were obtained from the Mississippi State University Department of Agricultural Economics 2012-2015 Soybean Planning Budgets and actual purchase prices of fertilizer obtained from BWI in Memphis in 2014. Fertilizer prices used in economic assessment calculations were muriate of potash, $.27/lb; triple superphosphate, $0.27/lb; MgS, $0.29/lb; S, $0.27/lb; Mn, $1.10/lb; B, $0.95/lb; Zn, $0.89/lb; and Cu, $2.15/lb. Soybean prices used in economic calculations were based on the 4-year average of $12.52/bu from 2012 to 2015 (USDA-NASS).

An analysis of variance was conducted using PROC ANOVA in SAS version 9.3 (SAS Institute Inc., Cary, NC). Soybean yield was presented separately by year and as a 3-year average to illustrate the influence of different weather conditions. Treatment differences were determined using Fisher's Protected LSD ($P \leq 0.05$). Quadratic relationships were defined using the PROC REG procedure in SAS version 9.3 (SAS Institute Inc., Cary, NC).

Objective 1.

The public lab recommended K_2O at 60 lb/A each year from soil samples collected from the same irrigated or dryland plots that utilized the public lab fertilizer strategy. The private lab recommendations changed each year, with yield goals of 40 and 70 bu/acre from dryland and irrigated environments, respectively (Table 1). Public lab fertilizer recommendations for dryland production with a 40 bu/acre yield goal decreased each year, while recommendations for a 70 bu/acre yield goal from the irrigated environments decreased after year 1 and remained the same in years 2 and 3 for fertilizer P_2O_5 and K_2O. In addition, S was recommend each year, Mn and Mg was added in year 2 and 3, and the addition of B was included in year 3. Private lab recommendations for 40 and 70 bu/acre yield goals were similar for years 1 and 2, but increased in year 3 with the addition of B.

Soybean yield was no different with soil test recommendations from public and private labs when averaged across variety and irrigation practice (Table 2). Yields ranged from 59.0 to 60.9, 50.3 to 50.7, and 59.1 to 60.9 bu/acre for all soil testing lab treatments in 2012, 2013, and 2014, respectively. Yield with all fertilizer treatments from soil testing lab recommendations were higher than the untreated check. The 3-year average yield of combined varieties for irrigated soybean was higher than dryland regardless of soil testing lab treatment (Figure 1). Irrigated soybean yields ranged from 59 to 61 bu/ac and nonirrigated soybean yields ranged from 53 to 56 bu/acre. Yield from dryland public and private soil testing lab treatments was equal to or greater than the irrigated untreated treatment. Yield from the untreated dryland system was less than all other treatments.

Soybean yield with fertilizer treatments recommended by public and private labs ranged from 59 to 60 bu/acre for the genetically enhanced variety Asgrow 5332 and 53 to 55 bu/acre for the conventional Hutcheson variety, respectively (Figure 2). Yield Asgrow 5332 was greater than yield of Hutcheson regardless of fertility treatment. This indicates a higher yield potential for the newer variety. Even though the addition of fertilizer did increase yield of both varieties compared to the untreated check, there was no difference in yield with different fertilizer treatments recommended by public and private soil testing labs.

Soybean yield across all fertilizer treatments from Asgrow 5332 was greater than yield from Hutcheson in both the irrigated and nonirrigated environments (Figure 3). The 3-year average soybean yield was 8 and 3 bu/acre higher for Asgrow 5332 than for Hutcheson in the irrigated vs. nonirrigated environments, respectively.

Objective 2.

The effect of potassium rate on soybean yield for both Asgrow 5332 and Hutcheson was evaluated with K_2O fertilizer applications ranging from 0 to 150 lb/acre to both irrigated and dryland environments. These treatments were not an attempt to establish soil test correlation/calibration studies, but rather were more as a supportive tool to manage performance of fertilizer recommendations. Yield response to K_2O fertilizer rate best fit a quadratic model, with R^2 values ranging from 0.63 to 0.96 (Figure 4). In addition, the response of net profit relative to yield and K_2O fertilizer rate was also best described as a quadratic relationship (Figure 5).

Estimated K_2O fertilizer rates to maximize yield and maximize net profit were based on these quadratic response models as described in Table 3. Even though this is a small data set from a few years, it does provide a "snapshot" to gauge how well the recommended fertilizer rates performed relative to yield and net profit. The estimated K_2O rate to achieve maximum yield compared to the rate for maximum net profit was 19 and 24 lb/acre higher for dryland and 25 and 36 lb/acre higher for irrigated environments with Asgrow 5332 and Hutcheson, respectively. The increase in yield with these higher rates of K_2O was 0.5 and 0.6 bu/acre for dryland and 0.3 and 0.4 bu/acre for irrigated environments with Asgrow 5332 and Hutcheson, respectively. In addition, net profit increased from $5.44 and $7.95/acre for dryland and $4.28 and $5.43/acre for irrigated environments for Asgrow 5332 and Hutcheson, respectively.

Objective 3.

The highest net return to fertilizer among recommendations from all soil testing labs was $763/acre achieved with the public lab fertilizer rate for Asgrow 5332 in an irrigated environment (Table 4). Net return to fertilizer was highest with irrigated compared to dryland production for Asgrow 5332 and followed the order of public lab, private lab (40 bu/acre yield goal), untreated, and private lab (70 bu/acre yield goal). Net return to fertilizer recommendations for dryland Asgrow 5332 followed this same order of performance. There was not a clear performance order for recommendations for Hutcheson, but net return to fertilizer was highest with the pubic lab fertilizer rate for both irrigated and dryland production systems.

A comparison of estimate vs. actual net net return to fertilizer with soil test lab recommendations reveals that the public lab was the most similar to achieving the maximum estimated net return as described by the fertilizer rate response curve (Table 3). Estimates and actual net return to fertilizer using public lab recommendations were $748 and $763/acre for irrigated Asgrow 5332, $690 and $692/acre for dryland Asgrow, $664 and $652/acre for irrigated Hutcheson, and $640 and $648/acre for dryland Hutcheson, respectively. Hence, net return to fertilizer was higher with public lab recommendations vs.those from the private lab when comparing similar varieties and production practices.

IMPACTS AND BENEFITS TO MISSISSIPPI SOYBEAN PRODUCERS

This research indicates that it is important to include a fertilizer treatment in Mississippi soybean production systems. The best way to determine an appropriate fertilizer rate is to collect a soil sample and send it to a soil testing laboratory for analysis. It might even be worth the investment to send a few samples to multiple labs and compare analysis of soil test nutrient levels and rate of fertilizer each lab recommends. This would help determine if fertilizer recommendations from a certain soil testing lab might be more appropriate for developing a nutrient management plan for a farming operation, since this research indicates that different soil testing labs may make different fertilizer recommendations for the same soil sample.

In some cases, the recommended rate may be higher than necessary to achieve the best return on investment. Based on this research for a Falkner silt loam soil, if 25% of the estimated 2.25 million acres of soybean did not receive a fertilizer application when the nutrient status of the soil tested at a level low enough to prompt fertilization, there is a potential for more than $35 million in lost revenue. On the other hand, if 25% of the 2.25 million acres were over-fertilized based on a 70 bu/acre yield goal recommendation, there is the potential for more than $25 million in lost revenues. Therefore, it is important to consider historical yields and climatic conditions before requesting a recommendation for a high yield goal.

END PRODUCTS-COMPLETED OR FORTHCOMING

Results from this research were presented at the Southern Association of Agriculture Scientists and the American Society of Agronomy Meetings. Also, at least two informational videos were recorded for the Mississippi Soybean Promotion Board website. The PI plans to submit this information in the form of a MAFES bulletin in 2018.

Table 1. Soil test recommendations from private (40 and 70 bu/acre yield goals) and public soil testing labs for dryland and irrigated soybean production, plus associated costs, in no-tillage environments on a Falkner silt loam at the Pontotoc Ridge-Flatwoods Branch Experiment Station of Mississippi State University, 2012-2014.

	2012			2013					2014						
Soil Testing Laboratory	P_2O_5	K_2O	S	P_2O_5	K_2O	S	Mn	Mg	P_2O_5	K_2O	S	Mn	Mg	B	Avg. Cost
	lb/acre														$/A
Private 40 dryland	30	94	13	30	67	13	2	11	0	65	2	2	9	0.5	69.23
Private 70 dryland	46	136	13	46	113	15	2	19	46	113	3	0	10	0.5	104.45
Public dryland	0	60	0	0	60	0	0	0	0	60	0	0	0	0	26.59
Private 40 irrigated	30	94	13	30	94	17	0	4	30	110	14	0	0	0.5	68.42
Private 70 irrigated	46	136	13	46	132	18	0	0	46	148	13	0	0	0.5	93.94
Public irrigated	0	60	0	0	60	0	0	0	0	60	0	0	0	0	26.59

Table 2. No-tillage soybean yield from 2012 to 2014 with soil test recommendations from private (40 and 70 bu/acre yield goals) and public soil testing labs averaged across varieties and dryland/irrigated treatments on a Falkner silt loam at the Pontotoc Ridge-Flatwoods Branch Experiment Station of Mississippi State University.

Lab Fertilizer	Soybean Yield		
Recommendation	2012	2013	2014
	Bu/acre		
Private 70 bu/acre	59.6	50.7	59.1
Private 40 bu/acre	59.0	50.5	60.9
Public	60.9	50.3	60.9
Untreated	56.1	44.6	52.8
LSD ($P \leq 0.05$)	4.5	3.2	3.1

Table 3. Estimated K_2O to maximize yield or net profit with rate-response curves of average yield and net profit from 2012 to 2014 for conventional and genetically enhanced soybean varieties in irrigated and dryland no-tillage environments on a Falkner silt loam at the Pontotoc Ridge-Flatwoods Branch Experiment Station of Mississippi State University.

Maximum Yield and Net Profit Estimates for Response Curves							
Soybean	Water	Maximize Yield			Maximize Profit		
Variety	Management	Yield	K_2O	Profit	Yield	K_2O	Profit
		bu/acre	lb/acre	$/acre	bu/acre	lb/acre	$/acre
Asgrow 5332	Irrigated	62.7	81	748.85	62.2	56	754.29
	Dryland	58.0	90	686.53	57.7	71	690.81
Hutcheson	Irrigated	56.1	105	656.05	55.5	69	664.00
	Dryland	54.0	94	634.97	53.6	70	640.40

Table 4. Average net profit from 2012 to 2014 with soil test recommendations from private (40 and 70 bu/acre yield goals) and public soil testing labs in irrigated and dryland no-tillage environments on a Falkner silt loam at the Pontotoc Ridge-Flatwoods Branch Experiment Station of Mississippi State University.

Average Net Profit with Soil Test Recommendations								
Soybean Variety	Irrigated				Dryland			
	Private 70 bu/acre	Private 40 bu/acre	Public Lab	Untreated	Private 70 bu/acre	Private 40 bu/acre	Public Lab	Untreated
	-- Net Profit ($/A) --							
Asgrow 5332	694	740	763	710	579	635	692	614
Hutcheson	634	617	652	627	535	580	648	591

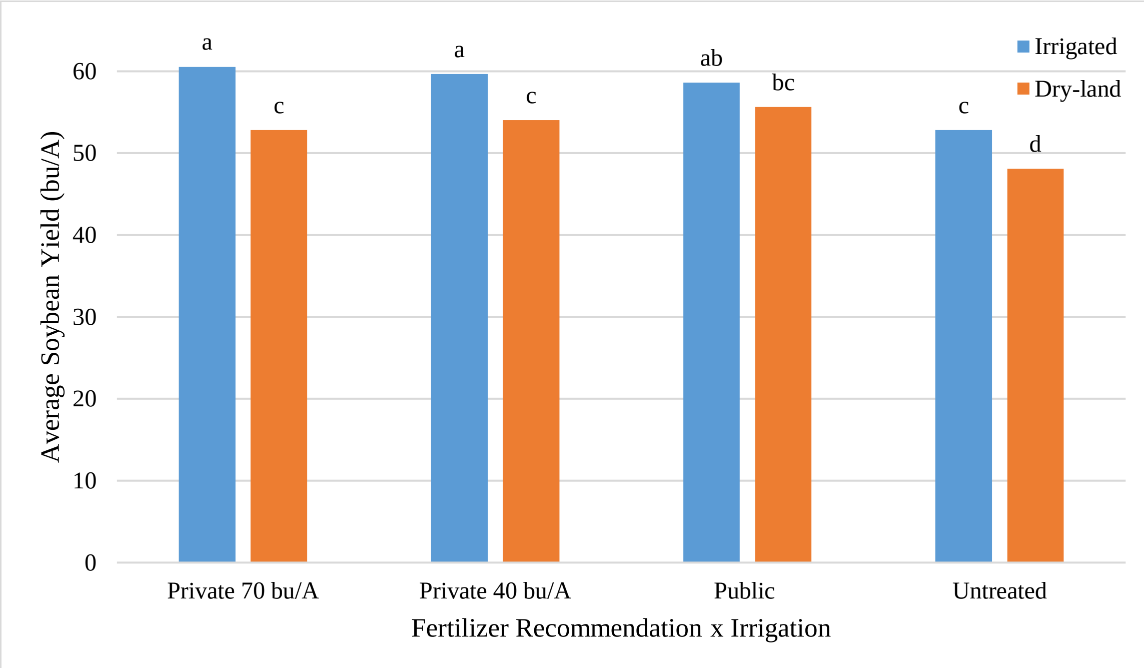

Figure 1. Average soybean yield (bu/acre) across cultivars over a 3-year period (2012 to 2014) from irrigated and dryland environments using different fertilizer recommendations from a public lab and a private lab (70 and 40 bu/acre yield goals) based on soil test results from the same soil sample (Mississippi State University, Pontotoc Ridge-Flatwoods Branch Experiment Station.)

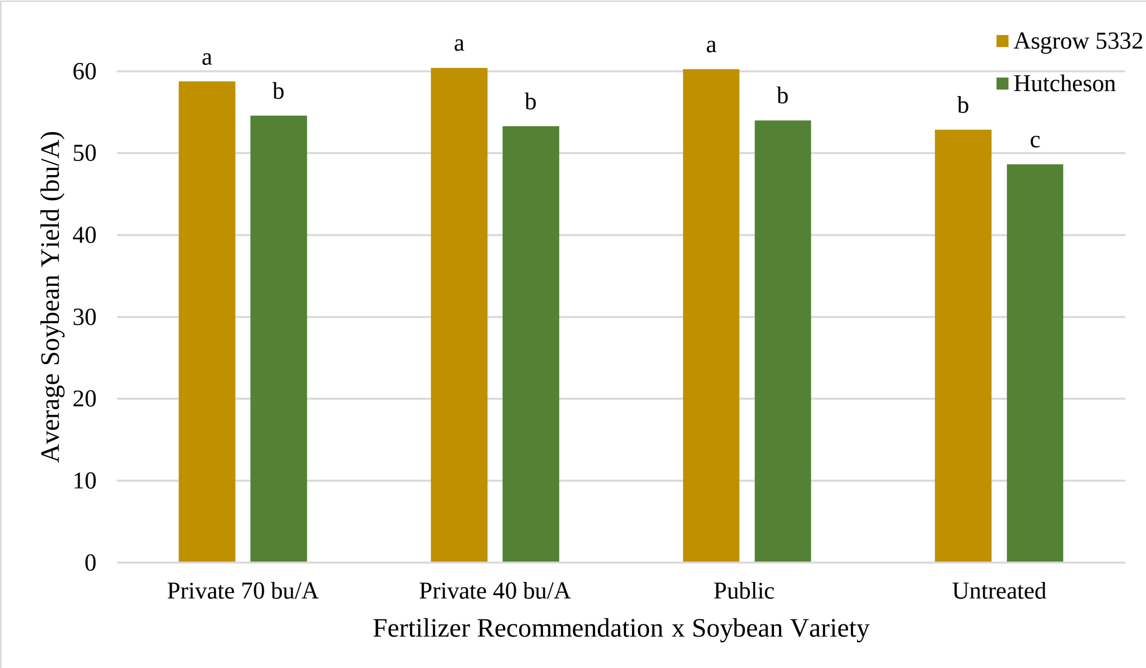

Figure 2. Average soybean yield (bu/acre) across irrigated and dryland environments over a 3-year period (2012 to 2014) using fertilizer recommendations from public and private soil testing labs and conventional and genetically enhanced varieties at the Mississippi State University, Pontotoc Ridge-Flatwoods Branch Experiment Station

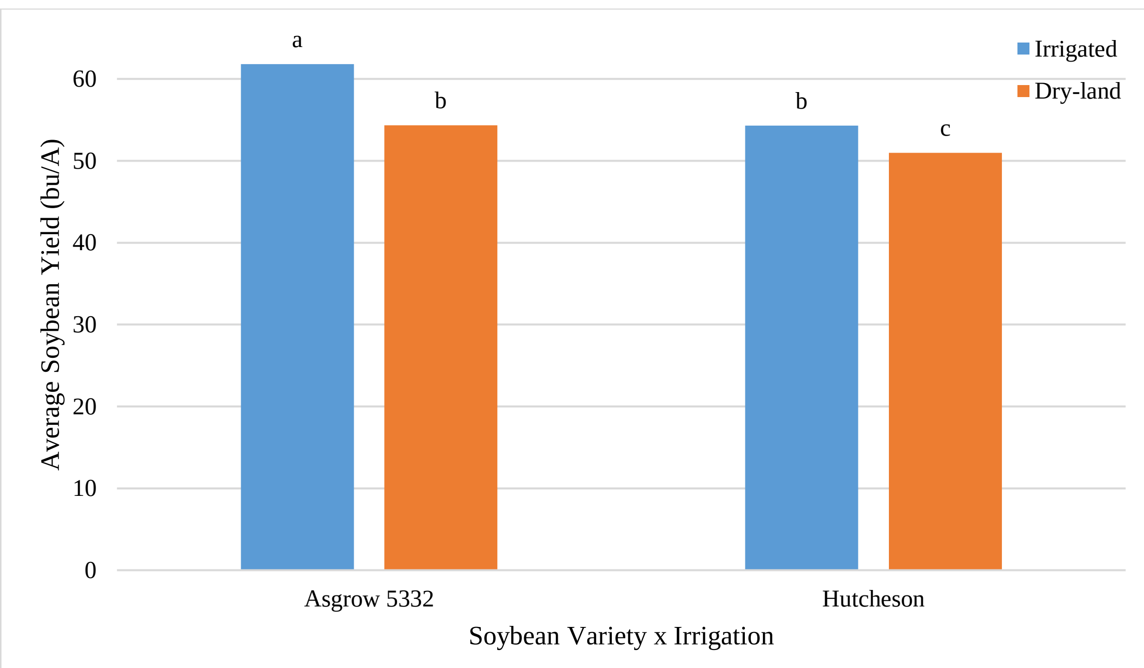

Figure 3. Average soybean yield (bu/acre) across fertilizer recommendations from public and private soil testing labs over a 3-year period (2012 to 2014) from irrigated and dryland environments and conventional or genetically enhanced varieties at the Mississippi State University, Pontotoc Ridge-Flatwoods Branch Experiment Station.

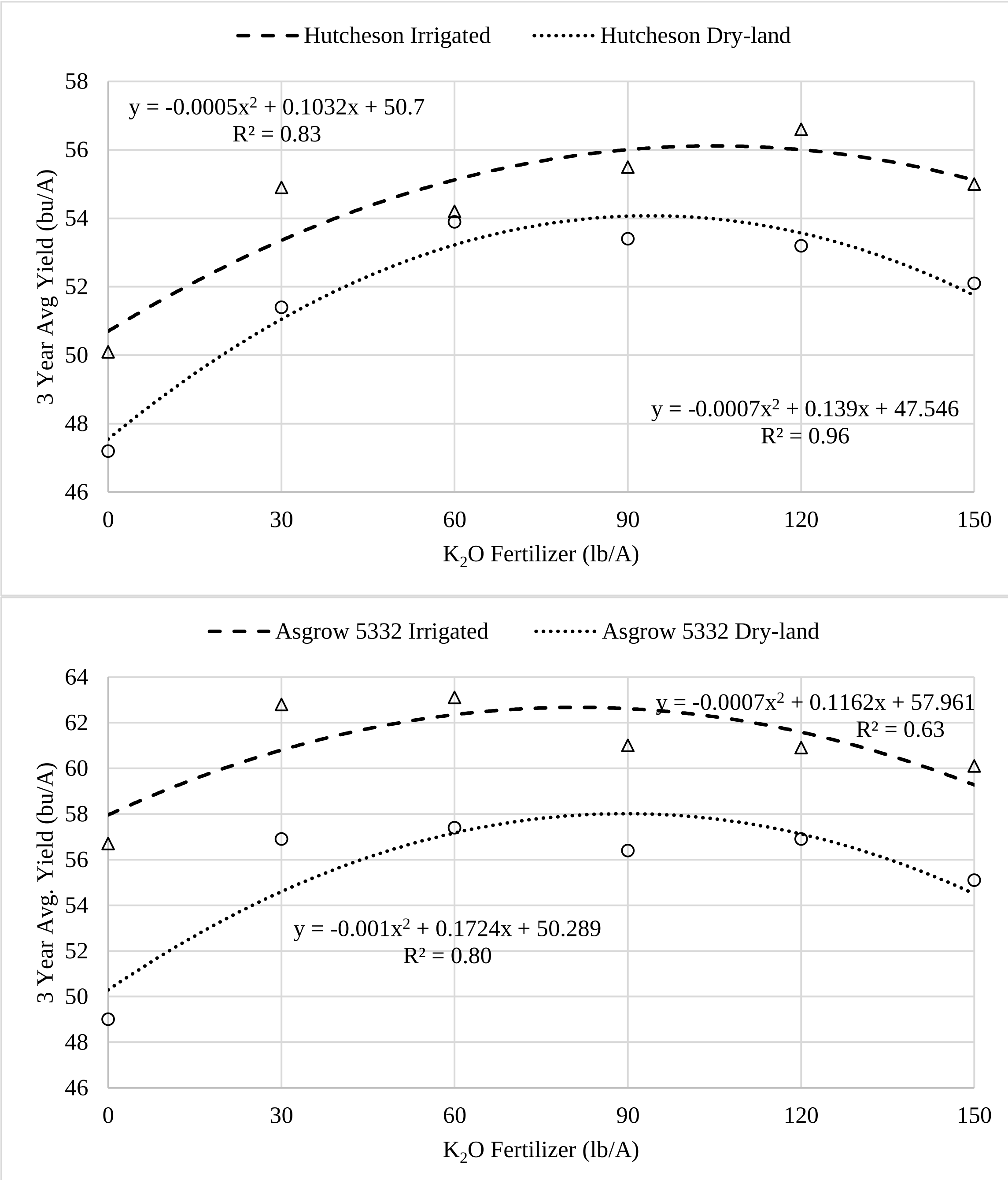

Figure 4. Quadratic response curves of predicted yield for no-tillage soybean produced in irrigated and dryland environments over a 3-year period (2012 to 2014) with K_2O fertilizer rates ranging from 0 to 150 lb/acre at the Mississippi State University, Pontotoc Ridge-Flatwoods Branch Experiment Station.

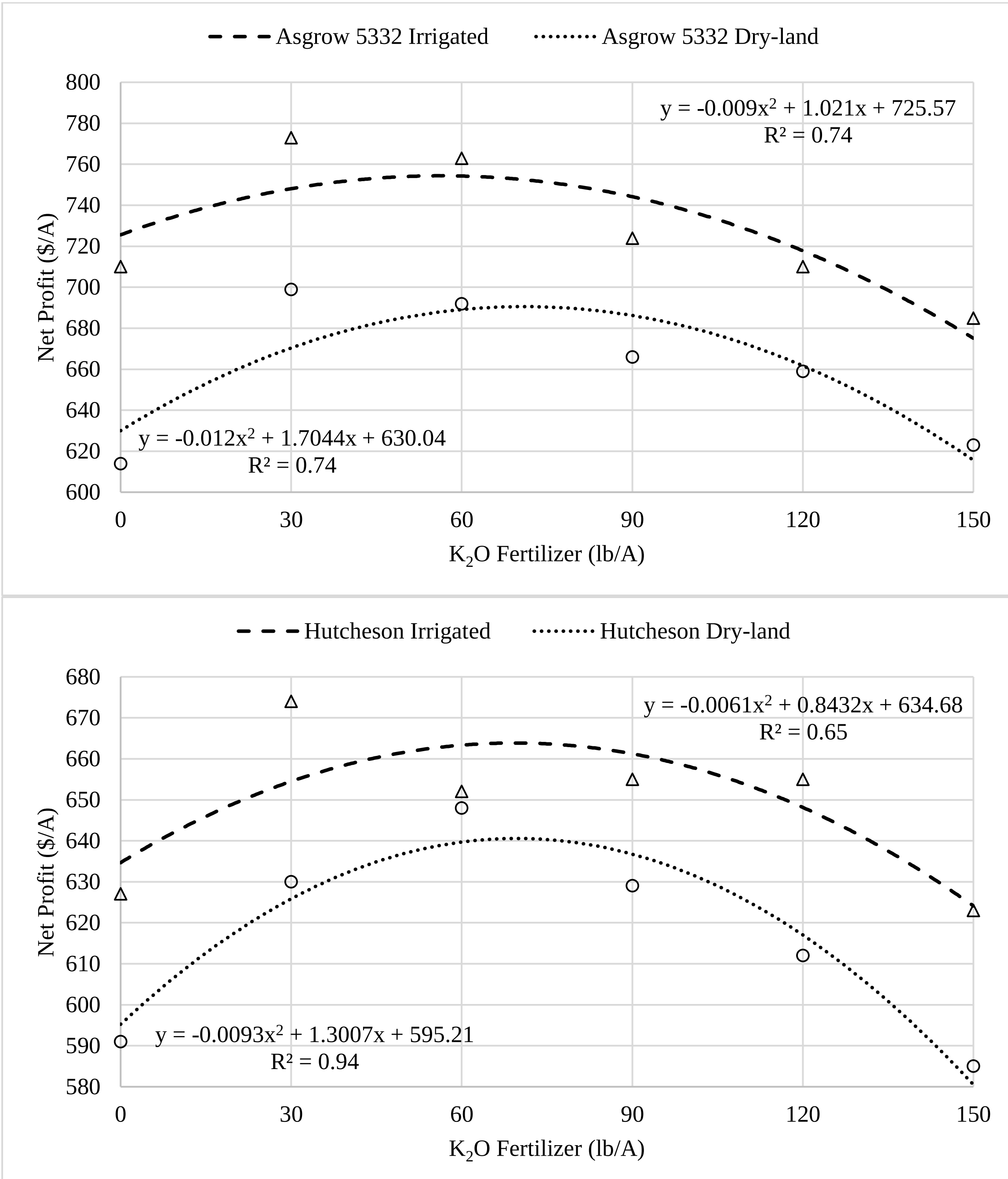

Figure 5. Quadratic response curves of predicted net return to fertilizer for no-tillage soybean produced in irrigated and dryland environments over a 3-year period (2012 to 2014) with K_2O fertilizer rates ranging from 0 to 150 lb/acre at the Mississippi State University, Pontotoc Ridge-Flatwoods Branch Experiment Station.