

Mid-South Soybean Board Quarterly Report

Project Title:	Evaluation of a novel drought-tolerant inoculant on soybean yield in the Mid-South (Year 2)
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Report Period:	December 16, 2020 - March 15, 2021

The objective of our field work this year is to evaluate the cross-inoculation effects of our Texas-native TX-VA inoculant on the yield of different soybean varieties including drought-sensitive and drought-tolerant cultivars in TX, TN, MO, LA, MS, and AR. Thus, we have determined its nodulation efficiency, plant growth, and the final yield. This is accomplished by comparing the growth and yield of our inoculant to a commercial inoculant (i.e., Cell-Tech™) as well as a non-inoculated control under non-irrigated conditions. For the 2nd year trial (Year 2020), we set up the field trials in the 6 states. We have finished all harvesting and completed the data analysis. Detailed planting dates, mid-sampling dates, harvesting dates, and results and discussion are described in the Technical Report attached. In addition, we include some of figures and tables from the December quarterly report in order to provide complete results of the data analysis on plant dry weight, nodule enumeration, and soybean yields.

It has been well established that the microorganism *Bradyrhizobium japonicum* has a beneficial impact on soybean plants. Previously, we isolated TXVA strain that showed outstanding performance in nodulation, nitrogen fixation, and enhancing plant growth and production. To improve the inoculants' performance and optimize the benefits of biological nitrogen fixation in the Mid-South, we set up field trials to evaluate the effects of the drought-tolerant inoculant on soybean yield at drought-prone sites. For the first year trial (year 2019), three inoculation treatments (drought-tolerant inoculant TXVA, commercial inoculant Cell-Tech, and no inoculation) will be compared under irrigated vs. non-irrigated conditions at drought prone sites in the Mid-South. At the first sampling, the number of nodules per plant will be counted and nodule size will be measured. A second harvest of plants will be performed to evaluate final soybean seed production. The climate and weather factors (e.g., precipitation, temperature, and humidity) for each location will also be monitored.

At the completion of the proposed research, we expect to provide positive effects of the drought-tolerant inoculant on soybean profitability and aid Mid-South producers in better understanding of the potential benefits for biological nitrogen fixation. We believe that providing such information will allow soybean producers to advance the management of soybean plants and inoculants for economical and ecological benefits.

Technical Report

Texas A&M AgriLife Research Plot - Yoakum, Texas.

- Plant date: 4/1
- Nodule harvest (sampling) date: 6/8
- Final harvest date: 9/2
- Soybean varieties: TN16, CZ5515, Otoño
- Row spacing: 38"
- Treatments: TXVA, Cell-Tech, no inoculant in the non-irrigated condition.

This site is in collaboration with James Grichar, a senior research scientist at Texas A&M AgriLife research. The plot layout that we designed here has 3 treatments, 3 cultivars, and 4 replicates. The cultivars used here were last year's variety TN-16, commercial seed CZ5515, and a Texas-specific variety Otoño. Plant dry weight and nodule enumeration are shown in Figs. 1 and 2, respectively.

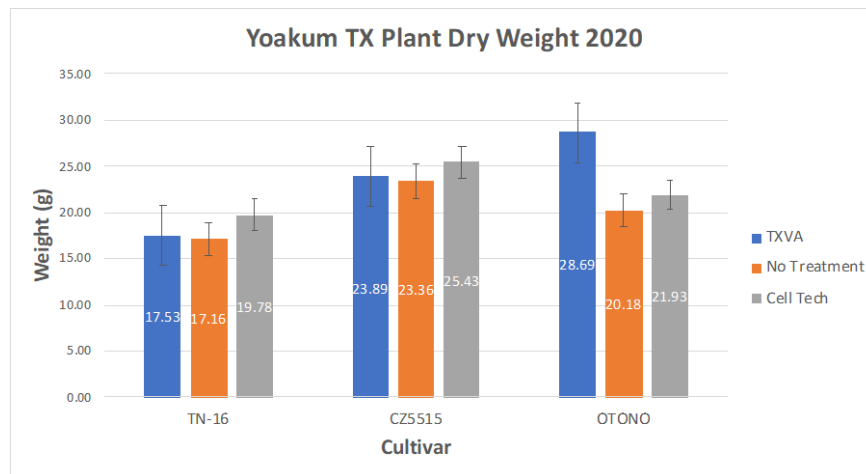


Figure 1. Plant dry weight in Yoakum, TX. The mid-samples were taken 9 weeks after planting.

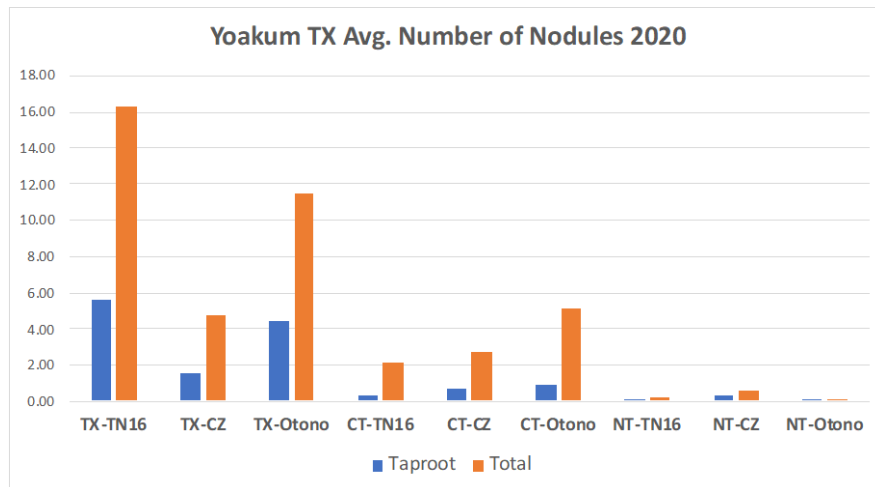


Figure 2. Taproot and total nodule counts in TN-16, CZ5515, and Otoño. TX, CT, and NT indicate TX-VA strain inoculation, Cell-Tech inoculation, and no inoculation, respectively.

As described in the December quarterly report, TX-VA performed better than Cell-Tech, although no treatment appeared to be as much effective as TX-VA in both TN-16 and CZ5515 cultivars (Table 1). Interestingly, in the case of the Texas-specific variety Otoño, TX-VA induced soybean yield more than 2 times compared to both Cell-Tech and no treatment under the non-irrigated condition.

Table 1. Soybean yield (Bu/A) in Yoakum, TX.

Inoculants	Yield (Bu/A)		
	TN-16	CZ5515	OTONO
TX-VA	19.4	12.4	10.7
Cell-Tech	14.0	7.60	5.9
No Treatment	20.0	12.4	3.1

Macon Ridge Research Station - Winnsboro, Louisiana.

- Plant date: 5/11
- Nodule harvest (sampling) date: 7/14
- Final harvest date: 9/16
- Soybean varieties: TN-16 520R1, CZ5515, USG-7496XTS
- Row spacing: 40”
- Treatments: TXVA, Cell-Tech, no inoculant in the non-irrigated condition.

This site is in collaboration with Dr. Trey Price at Louisiana State University AgCenter. This is a non-irrigated site with 3 cultivars, 3 treatments, and 5 replicates. Plant dry weight and nodule enumeration are shown in Figs. 3 and 4, respectively. The data analysis of the final yield has been completed.

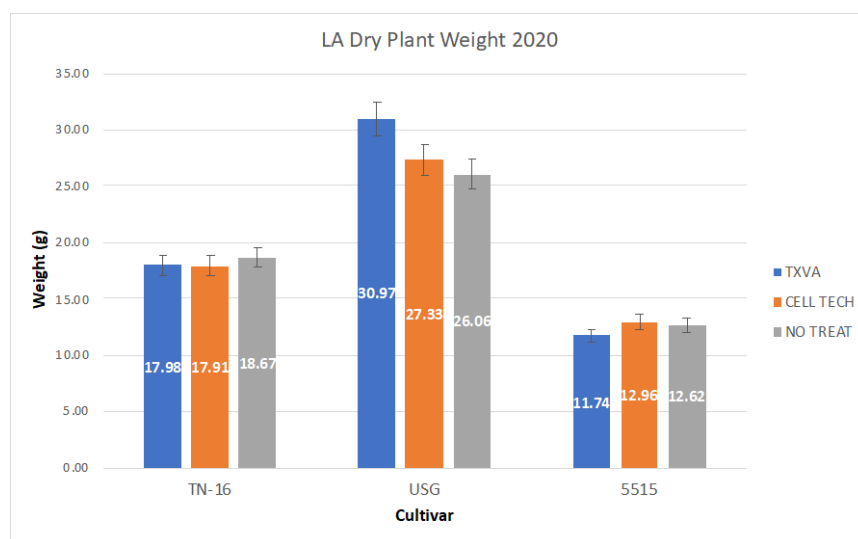


Figure 3. Plant dry weight in Winnsboro, LA. The mid-samples were taken 9 weeks after planting.

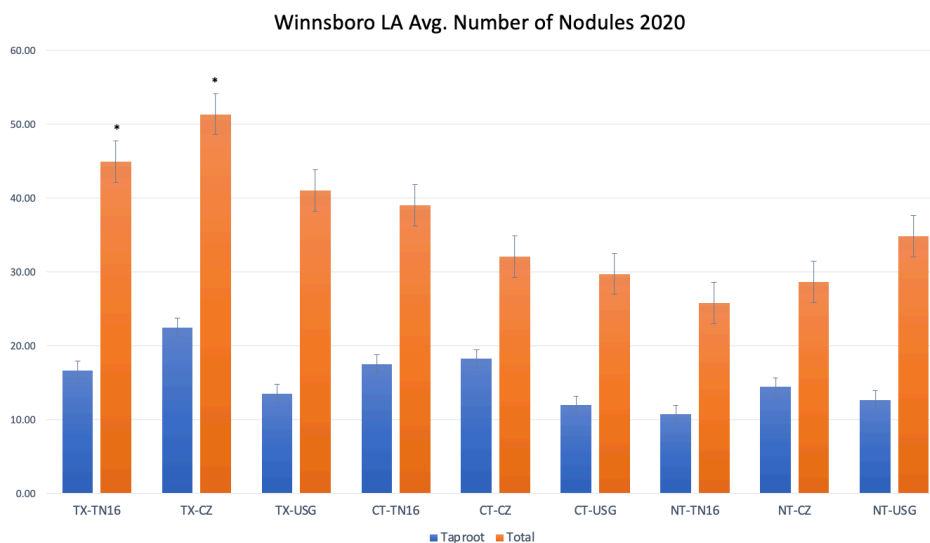


Figure 4. Taproot and total nodule counts in TN-16, CZ5515 (CZ), and USG-7496XTS (USG). TX, CT, and NT indicate TX-VA strain inoculation, Cell-Tech inoculation, and no inoculation, respectively.

Table 2 shows the final yield in Winnsboro, LA. Overall, TX-VA performed better than Cell-Tech, although no treatment appeared to be as much effective as TX-VA in TN-16, CZ5515, and USG cultivars under the non-irrigated condition.

Table 2. Soybean yield (Bu/A) in Winnsboro, LA.

Inoculants	Yield (Bu/A)		
	TN-16	CZ5515	USG
TX-VA	33.5	16.1	24.4
Cell-Tech	33.4	15.1	22.3
No Treatment	34.1	16.5	24.7

Tennessee Agricultural Experiment Station - Jackson, Tennessee.

- Plant date: 5/15
- Nodule harvest (sampling) date: 7/27
- Final harvest date: 10/21
- Soybean varieties: TN-16 520R1, USG-7496XTS
- Row spacing: 30"
- Treatments: TXVA, Cell-Tech, no inoculant in the non-irrigated condition.

This site is in collaboration with Dr. Avat Shekoofa at the University of Tennessee. The plot layout for TN is non-irrigated with 3 treatments and 2 cultivars with 4 replicates. Plant dry weight and nodule enumeration are shown in Figs. 5 and 6, respectively.

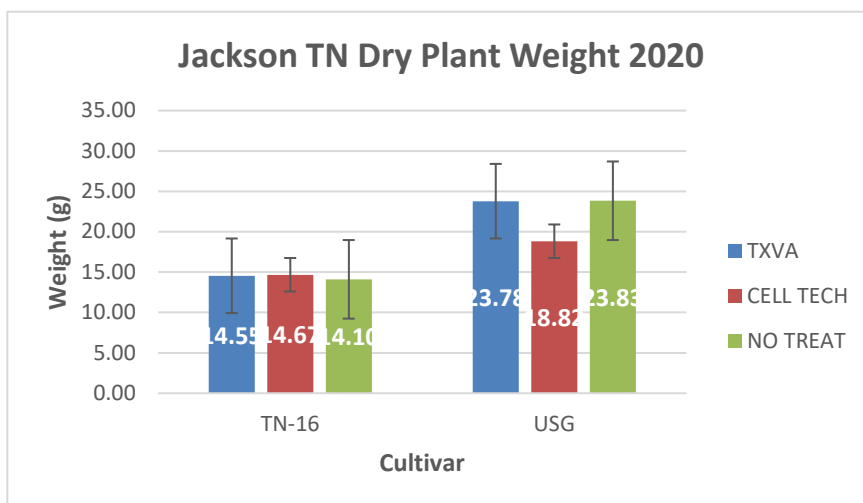


Figure 5. Plant dry weight in Jackson, TN. The mid-samples were taken 10 weeks after planting.

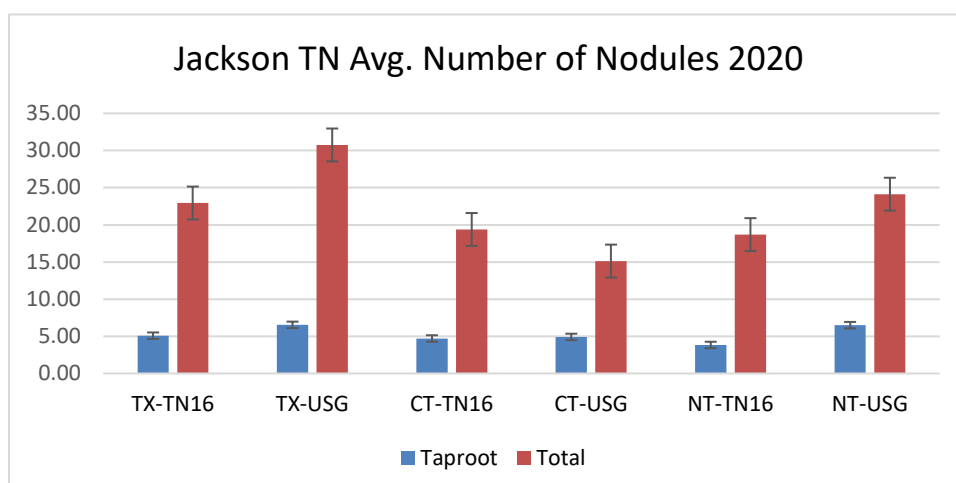


Figure 6. Taproot and total nodule counts in TN-16 and USG-7496XTS (USG). TX, CT, and NT indicate TX-VA strain inoculation, Cell-Tech inoculation, and no inoculation, respectively.

As described in the December quarterly report, no treatment showed the highest yield, even though TX-VA performed better than the commercial inoculant Cell-Tech (Table 3). More interestingly, for the drought-sensitive line USG-7496XTS, TX-VA strain enhanced soybean yield compared to both Cell-Tech and no treatment under the non-irrigated condition.

Table 3. Soybean yield (Bu/A) in Jackson, TN.

Inoculants	Yield (Bu/A)	
	TN16	USG
TX-VA	53.3	51.9
Cell-Tech	51.7	43.4
No Treatment	56.3	46.4

T.E. “Jake” Fisher Delta Research Center - Portageville, Missouri.

- Plant date: 6/2
- Nodule harvest (sampling) date: 7/28
- Final harvest date: 11/4
- Soybean varieties: TN-16 520R1, S14-9017R, S11-2024C
- Row spacing: 30”
- Treatments: TXVA, Cell-Tech, no inoculant in the non-irrigated condition.

This site is in collaboration with Dr. Pengyin Chen at the University of Missouri. The plot contains 3 cultivars, 3 treatments, and 6 replicates. The cultivars used were TN-16, S11-20242C drought-tolerant line, and S14-9017R drought-sensitive line. Plant dry weight and nodule enumeration are shown in Figs. 7 and 8, respectively. The data analysis of the final yield has been completed.

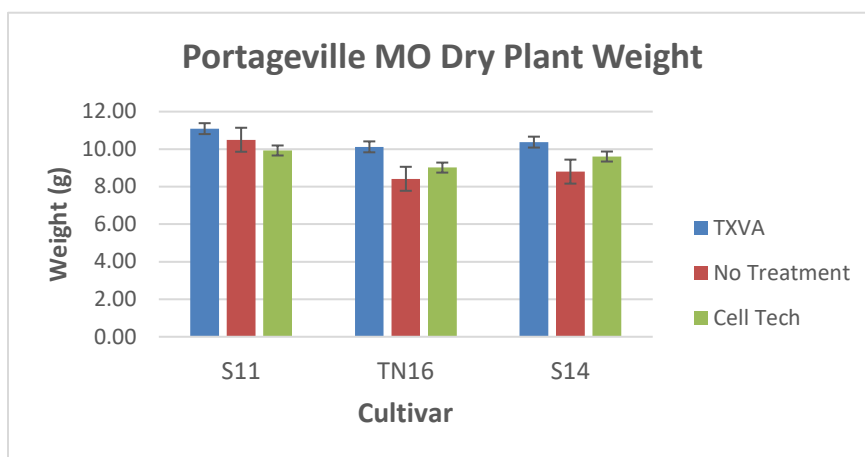


Figure 7. Plant dry weight in Portageville, MO. The mid-samples were taken 8 weeks after planting.

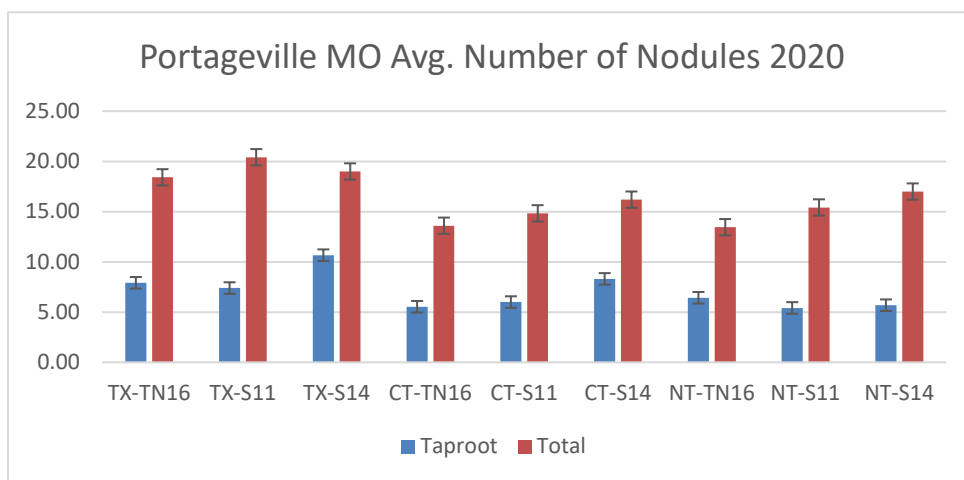


Figure 8. Taproot and total nodule counts in TN-16, S11-20242C (S11), and S14-9017R (S14). TX, CT, and NT indicate TX-VA strain inoculation, Cell-Tech inoculation, and no inoculation, respectively.

Table 4 shows the final yield in Portageville, MO. Overall, TX-VA performed better than Cell-Tech in all cultivars tested, specifically in the drought-sensitive cultivar S14-9017R, under the non-irrigated condition.

Table 4. Soybean yield (Bu/A) in Portageville, MO.

Inoculants	Yield (Bu/A)		
	TN-16	S14	S11
TX-VA	61.4	67.4	64.4
Cell-Tech	55.5	64.7	62.7
No Treatment	58.5	59.6	64.2

Stoneville USDA Agricultural Research Site - Leland, Mississippi.

- Plant date: 6/29
- Nodule harvest (sampling) date: 9/9
- Final harvest date: 10/29
- Soybean varieties: TN-16 520R1, S14-9017R
- Row spacing: 38"
- Treatments: TXVA, Cell-Tech, no inoculant in the non-irrigated condition.

This site is in collaboration with Dr. Tessie Wilkerson with Mississippi State. The plot layout reflects the same RCB design with 2 cultivars, 3 treatments, and 6 replicates. The cultivars used were TN-16 and drought-sensitive S14-9017R. Each block contains 4 rows of 15' with a 5' spacer row between blocks and a 38" row width. Plant dry weight is shown in Fig. 9, and nodule enumeration is shown in Fig. 10. The data analysis of the final yield has been completed.

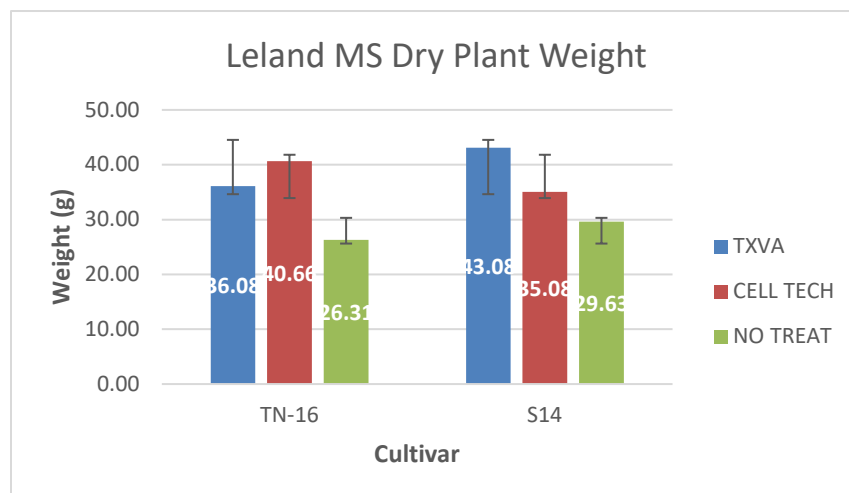


Figure 9. Plant dry weight in Leland, MS. The mid-samples were taken 9 weeks after planting.

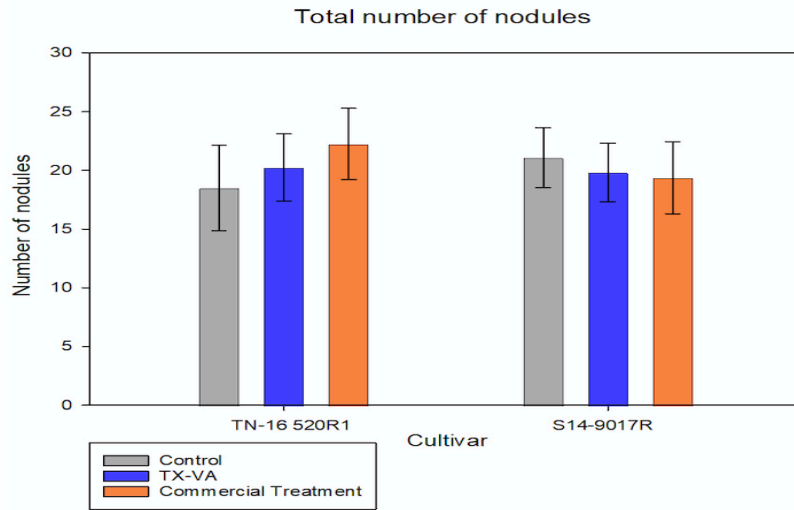


Figure 10. Total nodule counts in TN-16 and S14-9017R (S14) in Leland, MS. TX-VA, commercial treatment, and control indicate TX-VA strain inoculation, Cell-Tech inoculation, and no inoculation, respectively.

Table 5 shows mixed results. Cell-Tech performed better than TX-VA inoculant for TN-16, which is the different result compared to the last year’s yield data. However, for the drought-sensitive S14-9017R cultivar, TX-VA induced the highest yield among the three treatments under the non-irrigated condition.

Table 5. Soybean yield (Bu/A) in Leland, MS.

Inoculants	Yield (Bu/A)	
	TN-16	S14
TX-VA	46.8	58.0
Cell-Tech	53.2	49.4
No Treatment	49.0	52.9

Rice Research and Extension Center- Stuttgart Arkansas.

- Plant date: 7/1
- Nodule harvest (sampling) date: 9/10
- Final harvest date: 11/7
- Soybean varieties: TN-16 520R1, S14-9017R
- Row spacing: 30”
- Treatments: TXVA, Cell-Tech, no inoculant in the non-irrigated condition.

Our Arkansas site is in collaboration with Dr. Leandro Mozzoni from the University of Arkansas. The plot layout reflects the same RCB design with 2 cultivars, 3 treatments, and 5 replicates. The cultivars used were TN-16 and drought-sensitive S14-9017R. Each block contains 4 rows of

15' and 30" row width. Plant dry weight is shown in Fig. 11, and nodule enumeration is shown in Fig. 12. The data analysis of the final yield has been completed.

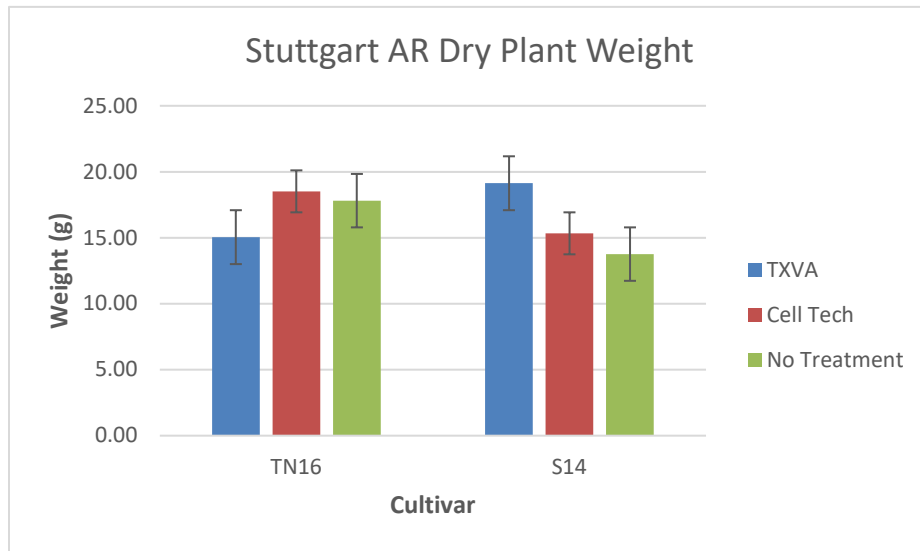


Figure 11. Plant dry weight in Stuttgart, AR. The mid-samples were taken 10 weeks after planting.

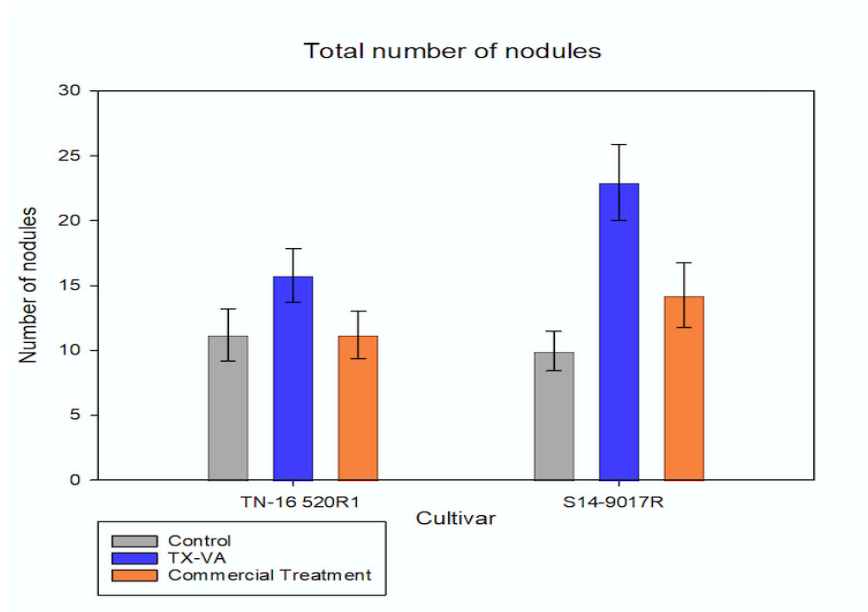


Figure 12. Total nodule counts in TN-16 and S14-9017R (S14) in Stuttgart, AR. TX-VA, commercial treatment, and control indicate TX-VA strain inoculation, Cell-Tech inoculation, and no inoculation, respectively.

Table 6 shows the final yield in Stuttgart, AR. For both TN-16 and the drought-sensitive cultivar S14-9017R, TX-VA performed better than Cell-Tech and no treatment under the non-irrigated condition.

Table 6. Soybean yield (Bu/A) in Stuttgart, AR.

Inoculants	Yield (Bu/A)	
	TN-16	S14
TX-VA	27.5	24.4
Cell-Tech	26.5	21.6
No Treatment	22.6	22.3

In summary, we have completed the analysis of yield data, plant dry weight, and nodule enumeration in all six states (TX, LA, TN, MO, MS, and AR) for testing our novel Texas-native drought-tolerant *Bradyrhizobium* inoculant with numerous soybean cultivars under the non-irrigated condition across drought prone regions. Table 7 shows a summary of planting dates, mid-sampling dates, and harvesting dates, while Table 8 shows comparison of yield data for different varieties inoculated with TX-VA or Cell-Tech under the non-irrigated condition in the six states.

Table 7. Summary of each filed site in 2020.

Location	Planting date	Nodule Sampling	Harvest	Cultivars used	Maturity Group
Yoakum, TX	4/1	6/6	9/2	TN16, CZ5515, Otoño	4L, 5, N/A
Winnsboro, LA	5/11	7/14	9/16	TN16, USG-7496*, CZ5515	4L, 4L, 5
Jackson, TN	5/15	7/27	10/21	TN16, USG-7496*	4L, 4L
Portageville, MO	6/2	7/28	11/4	TN16, S1120242C**, S14-9017R*	4L, 5, 5
Stoneville, MS	6/29	9/9	10/29	TN16, S14-9017R*	4L, 5
Stuttgart, AR	7/1	9/10	11/7	TN16, S14-9017R*	4L, 5

* = drought-sensitive

** = drought-tolerant

Table 8. Comparison between TXVA and Cell-Tech inoculants on the final yield of several cultivars under the non-irrigated condition in TX, LA, TN, MO, MS, and AR.

<i>Final Yield (Bushels/acre)</i>	Yoakum, TX		Jackson, TN		Portageville, MO		
	TN16	CZ5515LL	TN16	USG-7496	TN-16	S14	S11
TXVA	19.4	12.4	53.3	51.9	61.4	67.4	64.4
Cell-Tech	14.0	7.6	51.7	43.4	55.5	64.7	62.7
<i>Final Yield (Bushels/acre)</i>	Stuttgart, AR		Stoneville, MS		Winnsboro, LA		
	TN16	S14	TN16	S14	TN16	CZ5515LL	USG-7496
TXVA	27.5	24.4	46.8	58.0	33.5	16.1	24.4
Cell-Tech	26.5	21.6	53.2	49.4	33.4	15.1	22.3

Cultivar information: TN16, TN16-520R1 (MG 4L), the same cultivar used in the previous year (2019); CZ5515LL (tall, bushy MG 5); **USG-7496** (drought-sensitive MG 4L); **S14, S14-9017R** (drought-sensitive MG 5); **S11, S11-20242C** (drought-tolerant MG 5).