Effects of Harvest Aids on Seed Composition and Seed Damage in Soybean Grown in Mississippi
Project No: 32-2020

PI: Dr. Nacer Bellaloui
Email: Nacer.Bellalui@usda.gov

Background and Objectives

The transition to the use of the Early Soybean Production System in the Midsouth resulted in higher seed yields. However, with the shift towards the use of early-maturing soybean cultivars in the mid-South, the incidence of green stems, green pods, green leaf retention, and late-season weed infestation increased, thereby complicating harvest, reducing seed quality, and penalizing producers for increased seed moisture, foreign material and damaged seed at the elevator. Therefore, the use of harvest aids to defoliate green tissues in order to achieve uniformly dry plants at harvest, improve harvest efficiency, reduce elevator discounts and increase net returns is critical. Although several studies have been conducted on the effects of harvest aid application on yield, there is very limited information available on the effects of harvest aid on seed composition, mineral nutrition, and seed damage in soybean.

Paraquat is a common harvest aid used in the Midsouth that can also be effective in controlling grass and broadleaf weeds when applied late season. However, its application can cause significant crop damage if applied too early such as at the R5 or early R6 growth stages. Application of paraquat after physiological maturity (R7) decreased the number of green stems, green pods, and retained green leaves, allowing harvest 1 to 2 weeks earlier than non-treated soybean. Therefore, considering application timing of harvest aids on soybean is critical to maintain yield and seed quality. In the current research, paraquat (Gramoxone SL 2.0), as a harvest-aid, was applied at the label rate of 15 gallons/acre or 1 qt/acre) at the R6, R6.5, and R7 growth stages. A 1% of Fire Zone Methylated Seed Oil (MSO) was used for paraquat application. No paraquat was applied for the control. Therefore, there were four treatments (application of paraquat at R6, R6.5, R7, and the control). Two recent maturity IV commercial soybean cultivars were used (P46A57BX and P48A60X).

Objective One:
To evaluate the impact of timing of paraquat application on seed composition (protein, oil, fatty acids, sugars, and minerals) and seed quality (seed germination and FGIS seed damage) in soybean.

Report of Progress/Activity

The research was conducted at the USDA ARS Jamie Whitten Delta States Research Center at Stoneville, MS. The field trial was conducted using two recent commercial soybean cultivars of MG IV (P46A57BX and P48A60X) under irrigated conditions. Paraquat was applied at the concentration recommended by the label for use as a harvest-aid (15 gallons/acre or 1 qt/acre) at growth stages R6, R6.5, and R7. No paraquat was applied to soybeans used as the control. Soybeans were planted on May 1, 2019 using a 4-row-planter, and May 13, 2020 using an 8-row planter. The experiment was a randomized complete block design with ten replications. Each block contained all treatments (cultivars and paraquat timing application treatments). To avoid weathering effects, a 5-ft subsample of each of the two center rows of each plot was hand-harvested timely at full maturity (R8) for seed composition and seed damage analysis. The remainder of the center rows of each plot was harvested using a combine equipped with a load cell, allowing the harvest of the two center rows of each plot with their weights recorded separately. Seed composition constituents were analyzed using a near infra-red (NIR) instrument, and seed minerals were conducted by inductively coupled plasma (ICP) spectrometry, spectrophotometer, and C/N/S Elemental Analyzer. Seed quality traits, including hardseededness, were estimated by the State Seed Testing

Laboratory, Mississippi State, MS following the protocol of the Association of Official Seed Analysts (2001). Mature seed damage was estimated by seed graders certified by the Federal Grain Inspection Service (FGIS). Results showed that an application of paraquat at R6 resulted in significant reduction in yield for both cultivars compared with paraquat applied at R6.5, R7, or non-treated soybean (Table 1-Table 4). Additionally, application of paraquat resulted in yield reduction when applied at both R6 and R6.5 compared when applied at R7 or no application. This reduction was due to the fact that some pods at the lower canopy (lower section of the plants) were still growing and did not reach full maturity when the paraquat was applied). Also, results showed that application of paraquat, especially at R6 and R6.5, resulted in higher protein, oleic acid, and sugars (raffinose and stachyose), but decreased oil and sucrose (Table 5). Application of paraquat at R6 resulted in lower seed germination, viability, and seed damage in one year only for both cultivars (Table 5). No seed damage (FGIS) effect was recorded for either cultivar in all treatments, as FGIS was lower than 2%. FGIS includes grain damage due to multiple factors, including mold, heat, green seed, stink bug, and purple stain. Grain elevators assess discounts on the value of grain produced by soybean producers based on FGIS standards. This can result in a loss of revenue to producers when they sell their grain. A common level of grain damage that could result in discounting at grain elevators is the 2% level, meaning that damage >2% would result in discounting of payments to producers.

The overall results showed that application of paraquat at R6 and R6.5 resulted in significantly lower yield, oil, and sucrose, but significantly higher protein, oleic acid, and raffinose and stachyose sugars. Application of paraquat at R6 resulted in significantly lower seed germination and viability, but no seed damage above 2% was noticed in any treatment. The changes in seed composition observed from application of paraquat were due to the fact that paraquat is a chemical stress factor and the plant responded to it by shifting and redistributing these seed composition components for survival and completion of its life cycle. For most cases in this experiment, application of paraquat as a defoliant based either on seed moisture (as described in the literature: R6, i.e., 60% seed moisture based on moisture of soybean seed collected from uppermost 4 nodes of plants; R6.5, i.e., 50% seed moisture; or R7, i.e., 40% seed moisture) or growth stage determination according to Fehr and Caviness, 1977; or Whiting, Crookston, and Brun, 1988) resulted in lower seed yield because pods in the lower canopy of defoliated plants were still not fully mature; that is, they were apparently still in seed-fill mode. Therefore, growers should exercise caution in applying defoliants when pods are still green. They should weigh their options of applying a defoliant for increased harvest efficiency, but with possible yield loss, against greater yield with less harvest efficiency. Since seed composition constituents are still in the acceptable ranges in all treatments, growers may not worry about this aspect as no incentives are given for high seed protein or oil in conventional soybean cultivars.

Impacts and Benefits to Mississippi Soybean Producers

The use of early soybean cultivars in the Early Soybean Production System in the Midsouth (Arkansas, Louisiana, Mississippi, Missouri bootheel, and west Tennessee) has increased the incidence at harvest of green stems, green pods, green-leaf retention, and late-season weed infestation, complicating harvest and reducing seed quality. Green stems and leaves, when mixed with seed during harvest, increase moisture, foreign material, and seed damage, thereby decreasing net returns at the elevator. To achieve uniform harvesting, safely reduce moisture, and improve harvest efficiency, harvest aids are applied to the soybean crop to defoliate foliage and desiccate stems and remaining petioles. Therefore, the objective of this research was to evaluate the application of the harvest aid paraquat, as a commonly used harvest aid in the Midsouth, on soybean seed yield, seed composition (protein, oil, fatty acids, sugars, and minerals) and seed damage (FGIS seed damage).

Since it was known that the applying harvest aids too early (R6) can decrease yield and impact seed composition and seed damage, a study on the application timing of harvest aids was critical. Therefore, in this study, paraquat was applied at R6, R6.5, and R7 and a no-paraquat treatment was included as a control. Results showed that application of paraquat at R6 significantly reduced yield, and can affect seed germination and viability compared to application at R6.5, R7, and the no-paraquat control. Application of paraquat can also alter some seed composition constituents. Application of paraquat at R6.5, as noted in Crop Science and authored by Whiting, Crookston, and Brun, 1988), also reduced yield and altered seed composition germination, and viability. In this study, yield loss was also observed after paraquat application at R7 for one cultivar in two years and for the second cultivar in one year. No seed damage above 2% was observed for any treatment. This research will provide producers with useful information on the effects of harvest-aid application management (time of application) and its impact on seed yield, seed composition, seed damage, and potential dockage at the elevator. This information is critical for decisions made by producers to maintain yield and seed composition and keep seed damage to a minimum, avoiding losses in profit margins.

End Products–Completed or Forthcoming

Results from this research will be presented at the Mississippi Academy of Sciences Annual Meeting on "Effects of harvest aids on seed composition and seed damage in soybean grown in Mississippi", August 5-6, 2021. Other presentations given at different scientific and stakeholder meetings will follow afterwards. At least two manuscripts are planned on “The effects of harvest aids on seed yield, seed damage, and seed protein, oil, fatty acids, and sugars in soybean grown in Mississippi” to be submitted, hopefully, by the end of July, 2021, to a peer-reviewed journal (PLOS One or Plants or similar).

Graphics/Tables

Tables and Figures are below

Table 1. Effect of paraquat* at R6, R6.5, and R7 growth stages on soybean seed yield and seed composition (protein, oil, fatty acids, and sugars (sucrose, raffinose, and stachyose). The experiment was conducted in Stoneville, MS, in 2019.

		2019	Cultivar P46A57BX			
Stage application	Yield (kg/ha)	Protein (%)	Oil (%)	Palmitic (%)	Stearic (%)	Oleic (%)
Control	3740 (55.5 bu/ac)	39.11	25.31	10.10	4.59	22.09
R6	1815 (17.0)	40.83	21.88	9.70	4.24	27.21
R6.5	2986 (44.4)	38.84	24.27	10.06	4.53	20.89
R7	3565 (53.0)	38.79	24.77	10.00	4.53	22.06
LSD	69.5 (1.02)	0.202	0.13	0.21	0.059	0.55

		2019	Cultivar P46A57BX		
Stage application	Linoleic (%)	Linolenic (%)	Sucrose (mg/g)	Raffinose (mg/g)	Stachyose (mg/g)
Control	54.83	7.8	35.24	7.91	34.11
R6	53.50	7.73	21.29	9.87	44.30
R6.5	55.81	8.27	34.59	7.70	32.16
R7	54.68	7.71	39.20	8.05	33.94
LSD	0.48	0.23	1.02	0.096	0.857

* Paraquat was applied at the concentration recommended by the label for use as a harvest-aid (15 gallons/acre or 1 qt/acre) at growth stages R6, R6.5, and R7. No paraquat was applied to soybean that was used as a control. LSD = Least Significant Difference test, significant at $p \leq 0.05$. Within each column, the difference between two values is statistically significant if it equals or exceeds the corresponding LSD value.

Table 2. Effect of paraquat* at R6, R6.5, and R7 growth stages on soybean seed yield and seed composition (protein, oil, fatty acids, and sugars (sucrose, raffinose, and stachyose). The experiment was conducted in Stoneville, MS, in 2019.

		2019	Cultivar P48A60X			
Stage application	Yield (kg/ha)	Protein (%)	Oil (%)	Palmitic (%)	Stearic (%)	Oleic (%)
Control	4047 (60.6 bu/ac)	39.85	24.16	11.01	4.81	22.80
R6	1858 (27.6)	42.05	21.61	10.23	4.35	27.88
R6.5	3226 48.0)	39.51	23.37	10.48	4.65	21.55
R7	3848 (57.1)	39.37	23.85	10.56	4.71	22.16
LSD	84.60 (1.28)	0.24	0.12	0.21	0.07	0.57

		2019	Cultivar P48A60X		
Stage application	Linoleic (%)	Linolenic (%)	Sucrose (mg/g)	Raffinose (mg/g)	Stachyose (mg/g)
Control	52.17	8.56	40.10	8.21	33.56
R6	51.90	5.86	21.06	9.93	46.05
R6.5	53.90	8.53	38.52	7.87	32.40
R7	53.78	8.40	41.62	8.13	33.91
LSD	0.41	0.21	1.036	0.100	0.649

* Paraquat was applied at the concentration recommended by the label for use as a harvest-aid (15 gallons/acre or 1 qt/acre) at growth stages R6, R6.5, and R7. No paraquat was applied to soybean that was used as the control. LSD = Least Significant Difference test, significant at $p \leq 0.05$. Within each column, the difference between two values is statistically significant if it equals or exceeds the corresponding LSD value.

Table 3. Effect of paraquat* at R6, R6.5, and R7 growth stages on soybean seed yield and seed composition (protein, oil, fatty acids, and sugars (sucrose, raffinose, and stachyose). The experiment was conducted in Stoneville, MS, in 2020.

		2020	Cultivar P46A57BX			
Stage application	Yield (kg/ha)	Protein (%)	Oil (%)	Palmitic (%)	Stearic (%)	Oleic (%)
Control	2963 (44.1 bu/ac)	39.30	24.27	10.62	4.12	22.00
R6	1760 (26.18)	41.09	20.94	10.76	4.09	26.76
R6.5	2101 (31.24)	37.21	24.60	10.84	4.16	20.93
R7	2746 (40.81)	38.50	25.04	10.58	4.20	21.32
LSD	111 (1.65)	0.40	0.27	0.15	0.05	0.34

		2020	Cultivar P46A57BX		
Stage application	Linoleic (%)	Linolenic (%)	Sucrose (mg/g)	Raffinose (mg/g)	Stachyose (mg/g)
Control	58.55	7.63	39.90	7.47	33.37
R6	53.21	4.96	18.96	17.31	42.39
R6.5	58.35	8.35	34.83	7.37	32.33
R7	59.08	7.42	34.15	7.80	34.02
LSD	0.26	0.18	1.46	0.138	0.850

* Paraquat was applied at the concentration recommended by the label for use as a harvest-aid (15 gallons/acre or 1 qt/acre) at growth stages R6, R6.5, and R7. No paraquat was applied to soybean that was used as a control. LSD = Least Significant Difference test, significant at $p \leq 0.05$. Within each column, the difference between two values is statistically significant if it equals or exceeds the corresponding LSD value.

Table 4. Effect of paraquat* at R6, R6.5, and R7 growth stages on soybean seed yield and seed composition (protein, oil, fatty acids, and sugars (sucrose, raffinose, and stachyose). The experiment was conducted in Stoneville, MS, in 2020.

		2020	Cultivar P48A60X			
Stage application	Yield (kg/ha)	Protein (%)	Oil (%)	Palmitic (%)	Stearic (%)	Oleic (%)
Control	2701 (40.17 bu/ac)	39.54	23.25	11.20	4.28	23.38
R6	1879 (27.96)	41.25	21.10	11.61	4.38	27.63
R6.5	2201 (32.73)	37.68	24.08	11.20	4.33	22.68
R7	2814 (41.86)	39.41	23.17	11.28	4.35	21.85
LSD	187.32 (2.79)	0.300	0.205	0.163	0.059	0.373

		2020	Cultivar P48A60X		
Stage application	Linoleic (%)	Linolenic (%)	Sucrose (mg/g)	Raffinose (mg/g)	Stachyose (mg/g)
Control	57.18	7.10	42.32	7.52	36.20
R6	51.86	4.98	24.03	17.46	40.24
R6.5	57.12	7.98	38.27	7.25	31.33
R7	57.67	7.35	35.33	7.60	32.55
LSD	0.313	0.21	1.633	0.173	1.028

* Paraquat was applied at the concentration recommended by the label for use as a harvest-aid (15 gallons/acre or 1 qt/acre) at growth stages R6, R6.5, and R7. No paraquat was applied to soybean that was used as the control. LSD = Least Significant Difference test, significant at $p \leq 0.05$. Within each column, the difference between two values is statistically significant if it equals or exceeds the corresponding LSD value.

Table 5. Effect of paraquat* at the R6, R6.5, R7, and R8 growth stages on soybean seed germination, hared seed, viability, and seed damage (FGIS)*. The experiment was conducted in Stoneville, MS, in 2019 and 2020.

		2019	Cultivar P46A57BX	
Stage application	Germination (%)	Hard seed (%)	Viability (%)	Seed damage (FGIS) (%)
Control	47.6	16.6	64.1	0.62
R6	28.3	1.3	29.6	1.19
R6.5	47.9	21.9	69.8	0.98
R7	55.6	14.4	70.0	0.42
LSD	3.78	2.00	2.1	0.114
		2019	Cultivar P48A60X	
Stage application	Germination (%)	Hard seed (%)	Viability (%)	Seed damage (FGIS) (%)
Control	68.20	5.60	73.80	0.75
R6	30.89	1.44	32.33	1.02
R6.5	62.60	15.60	78.20	0.48
R7	67.4	9.70	77.10	0.51
LSD	3.27	1.83	2.03	0.16
		2020	Cultivar P46A57BX	

Stage application	Germination (%)	Hard seed (%)	Viability (%)	Seed damage (FGIS) (%)
Control	34.33	11.17	45.50	0.30
R6	50.29	11.29	61.57	0
R6.5	68.63	5.88	74.50	0
R7	57.50	12.33	69.83	0
LSD	5.35	2.69	4.90	0.054
		2020	Cultivar P48A60X	
Stage application	Germination (%)	Hard seed (%)	Viability (%)	Seed damage (FGIS) (%)
Control	51.80	7.20	59.00	0.38
R6	66.50	4.66	71.17	0.017
R6.5	81.50	3.33	84.83	0
R7	63.50	9.67	73.17	0
LSD	7.50	1.99	6.62	0.054

[*] Paraquat was applied at the concentration recommended by the label for use as a harvest-aid (15 gallons/acre or 1 qt/acre) at growth stages R6, R6.5, and R7. No paraquat was applied to soybean that was used as the control. LSD = Least Significant Difference test, significant at $p \leq 0.05$. Within each column, the difference between two values is statistically significant if it equals or exceeds the corresponding LSD value. FGIS includes grain damage due to multiple factors, including mold, heat, green seed, stink bug, and purple stain. A common level of grain damage that could result in discounting at grain elevators is the 2% level, meaning that damage >2% would result in discounting of payments to producers.

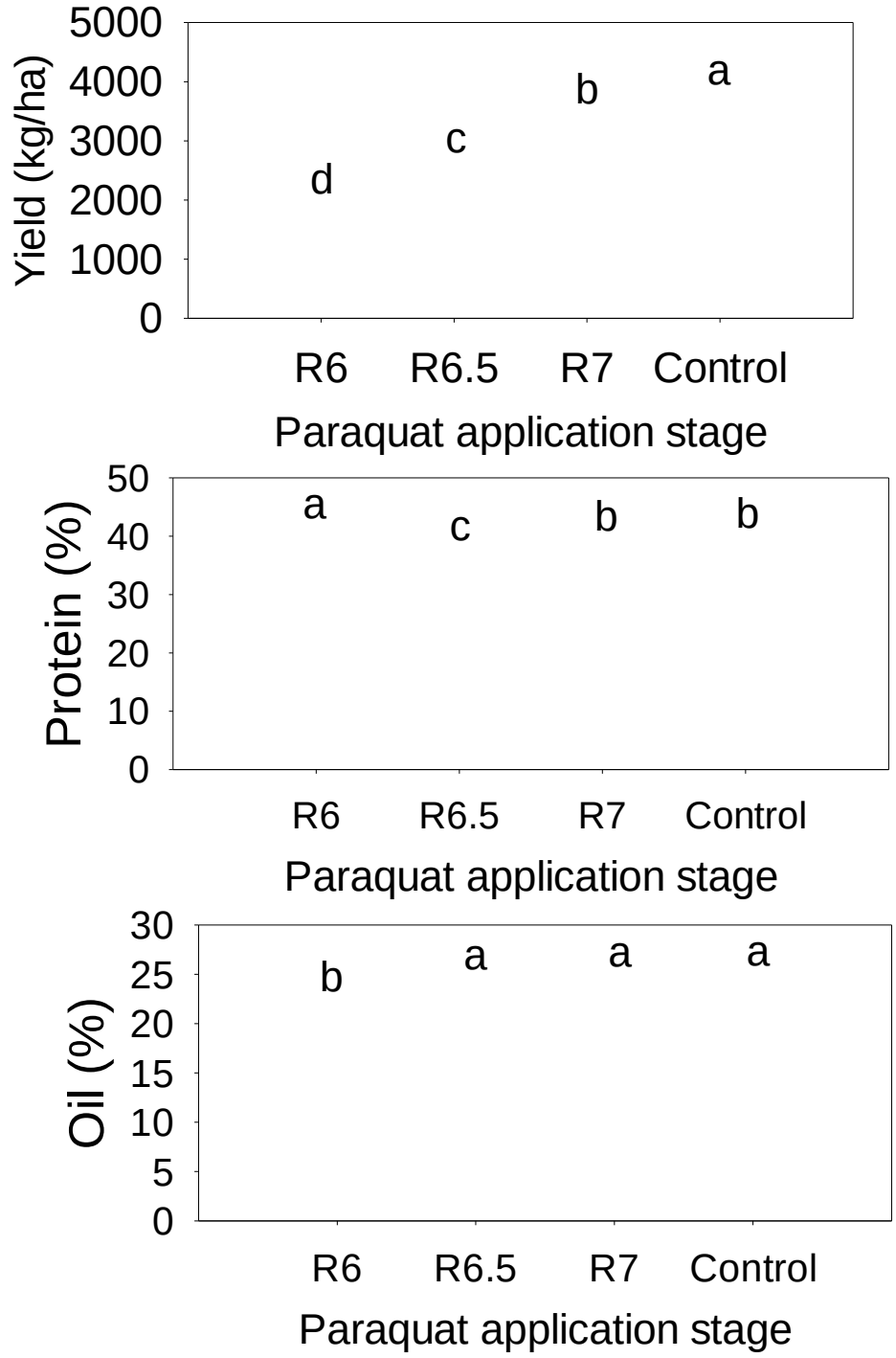

Figure 1. Effect of paraquat application at different growth stages on soybean seed yield, protein, and oil across two years (2019, 2020) and across two cultivars (P46A57BX and P48A60X). Growth stage 6.5 was determined according to Whiting, Crookston, and Brun, Crop Science, 28:866-867, 1988. Stage R6, R7, and R8 were according to Fehr and Caviness (1977)

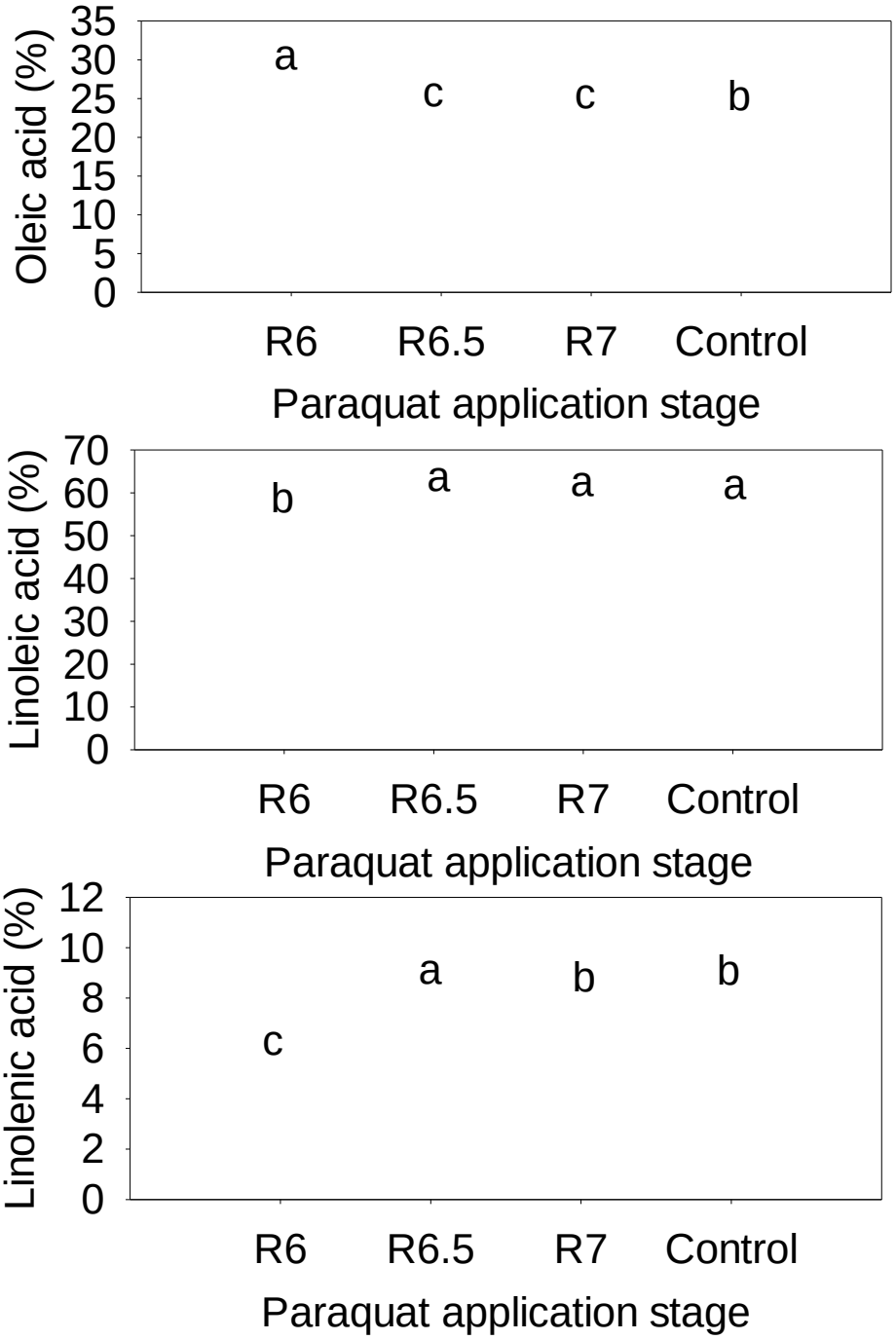

Figure 2. Effect of paraquat application at different growth stages on soybean seed oleic, linoleic, and linolenic acids across two years (2019, 2020) and across two cultivars (P46A57BX and P48A60X). Growth stage R6.5 was determined according to Whiting, Crookston, and Brun, Crop Science, 28:866-867, 1988, whereas stages R6, R7, and R8 were according to Fehr and Caviness (1977)

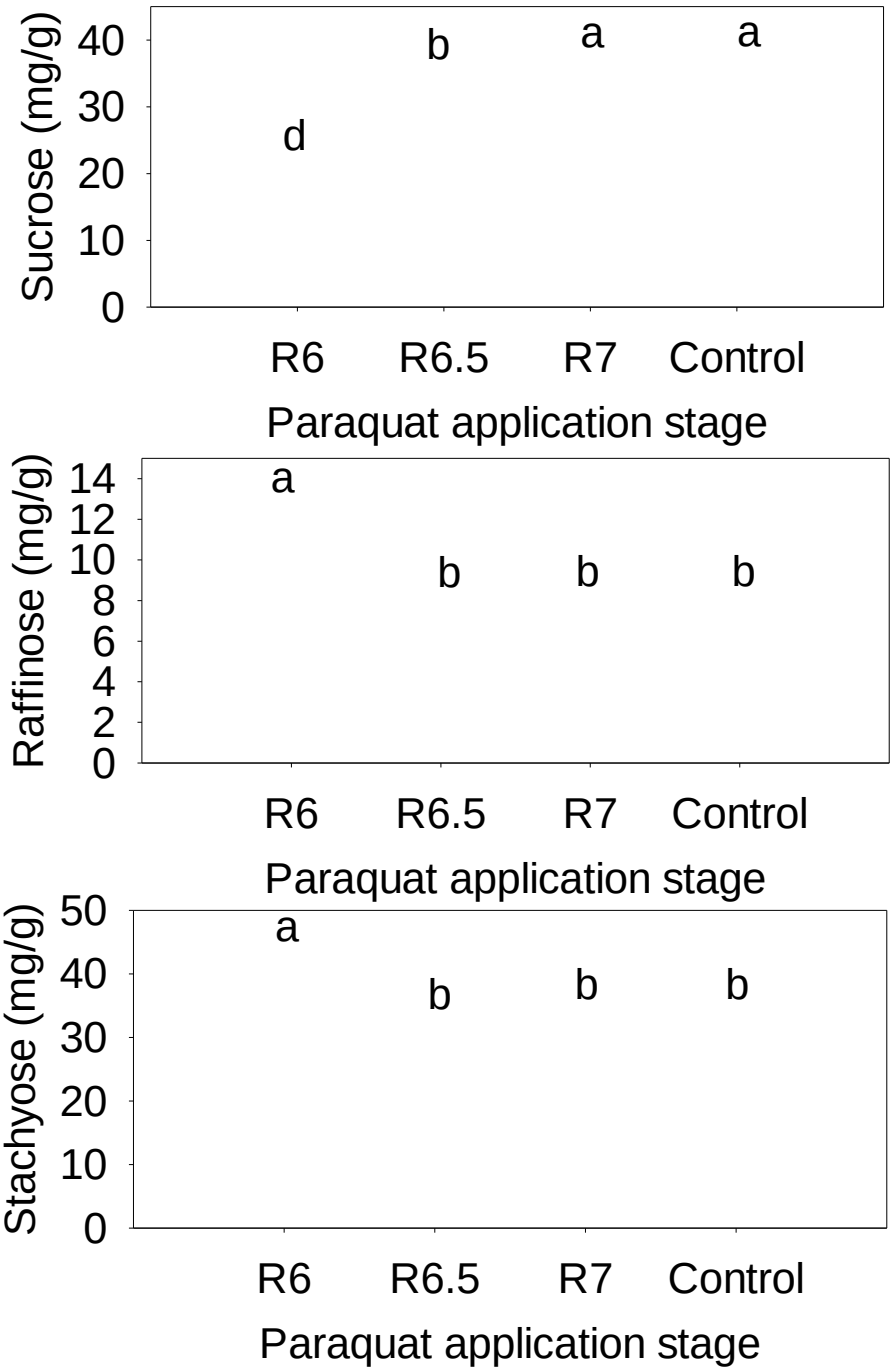

Figure 3. Effect of paraquat application at different growth stages on soybean seed sugars (sucrose, raffinose, and stachyose) across two years (2019, 2020) and across two cultivars (P46A57BX and P48A60X). Growth stage R6.5 was determined according to Whiting, Crookston, and Brun, Crop Science, 28:866-867, 1988, whereas stages R6, R7, and R8 were according to Fehr and Caviness (1977).

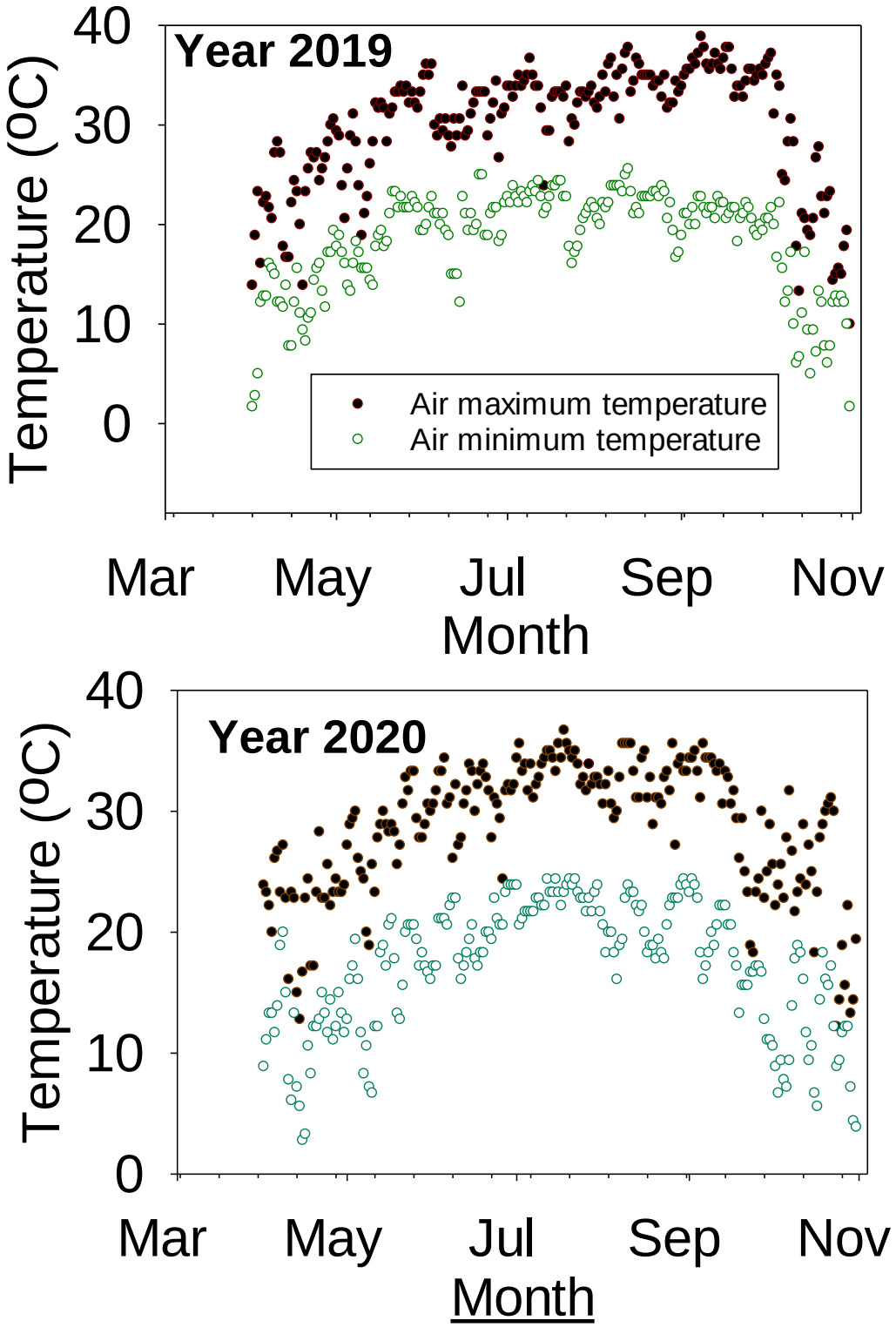

Figure 4. Air maximum and minimum temperature in 2019 and 2020. Data were obtained from Mississippi State University Extension. Delta Agricultural Weather Center at http://deltaweather.extension.msstate.edu/weather-station-result/

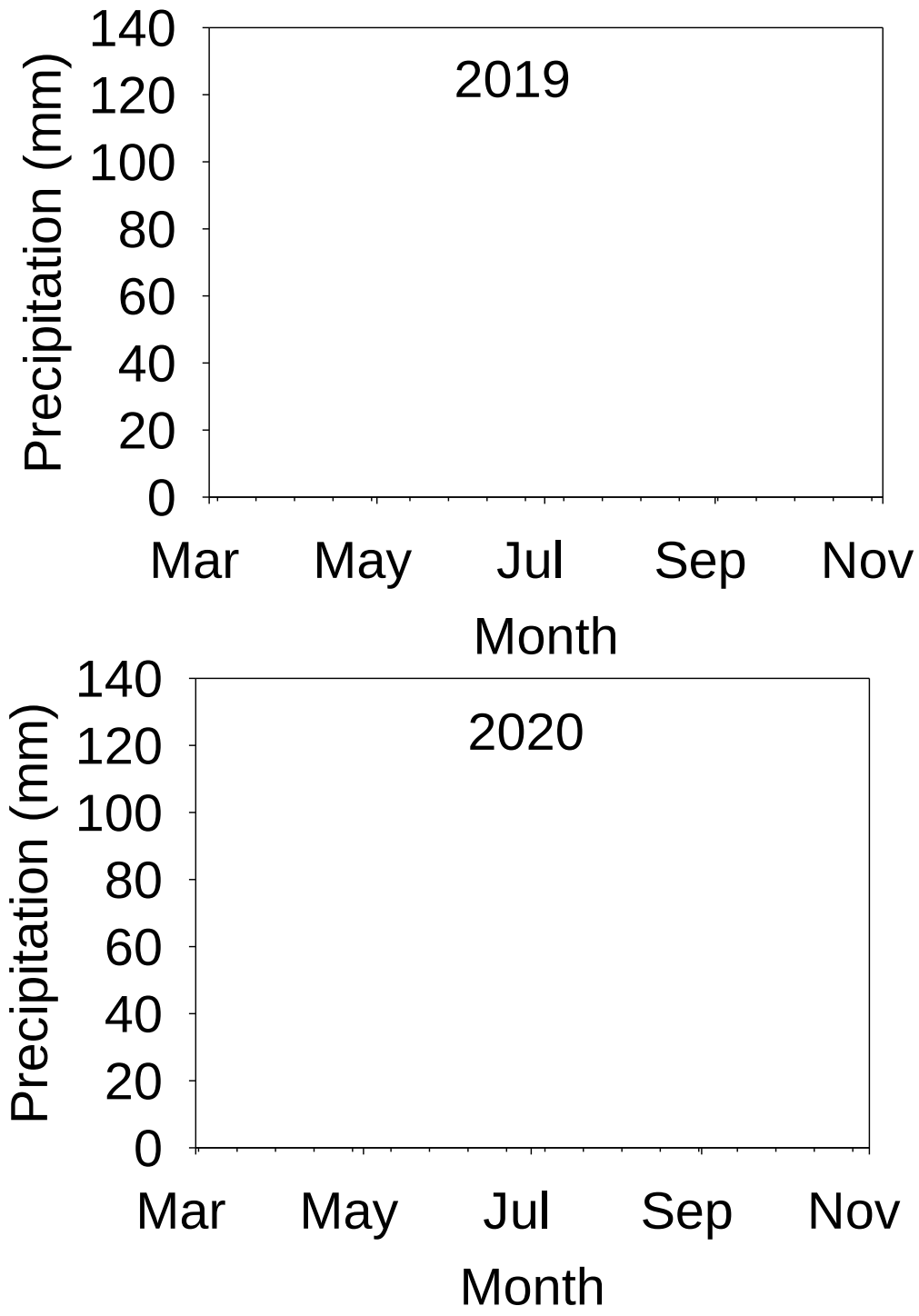

Figure 5. Precipitation in 2019 and 2020. Data were obtained from Mississippi State University Extension. Delta Agricultural Weather Center at http://deltaweather.extension.msstate.edu/weather-station-result/

Figure 6. Application of paraquat at R6 was 8/7/2019; Response of soybean after one day (8/8/2019) of paraquat application. Paraquat was applied to the two center rows. Cultivar was P46A57BX.

Figure 7. Application of paraquat at R6 was 8/7/2019; Response of soybean after six days (8/13/2019) of paraquat application. Paraquat was applied to the two center rows. Cultivar was P46A57BX.

Figure 8. Conrol (green plots/non-paraquat applied) and R6 plots, where paraquat was applied at the R6 growth stage. Picture was taken on September 14th, 2020. Paraquat application to R6 plots was on August 20th, 2020. Cultivar was P46A57BX.

Figure 9. A two-row harvester equipped with a load cell, allowing collection of yield data per each treatment. The picture was taken on October 27, 2020. Cultivar was P46A57BX.