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The Toll of Mid-Season Heat and Drought on Peanut Yield and Grade in Virginia

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Why This Matters to Growers

Mid-season heat and drought stress (HS+DS) severely impacts peanut growth, slashing yields by up to 50% and degrading kernel quality—key factors in market pricing (Puppala et al. 2023; Balota 2012& 2020). For Virginia-type peanuts, which command premium prices due to their large kernel size and superior grade (especially the "fancy" classification), HS+DS reduces both yield and percentage of total sound mature kernels (TSMK). This dual loss directly undermines profitability, as poor grades can offset gains from high productivity. With grade standards serving as a critical benchmark for growers and shellers, mitigating HS+DS is essential to preserving both yield and market value. This article discusses the effects of HS+DS on peanut yield and grade and highlights the importance of this combined stress.

Trial Overview

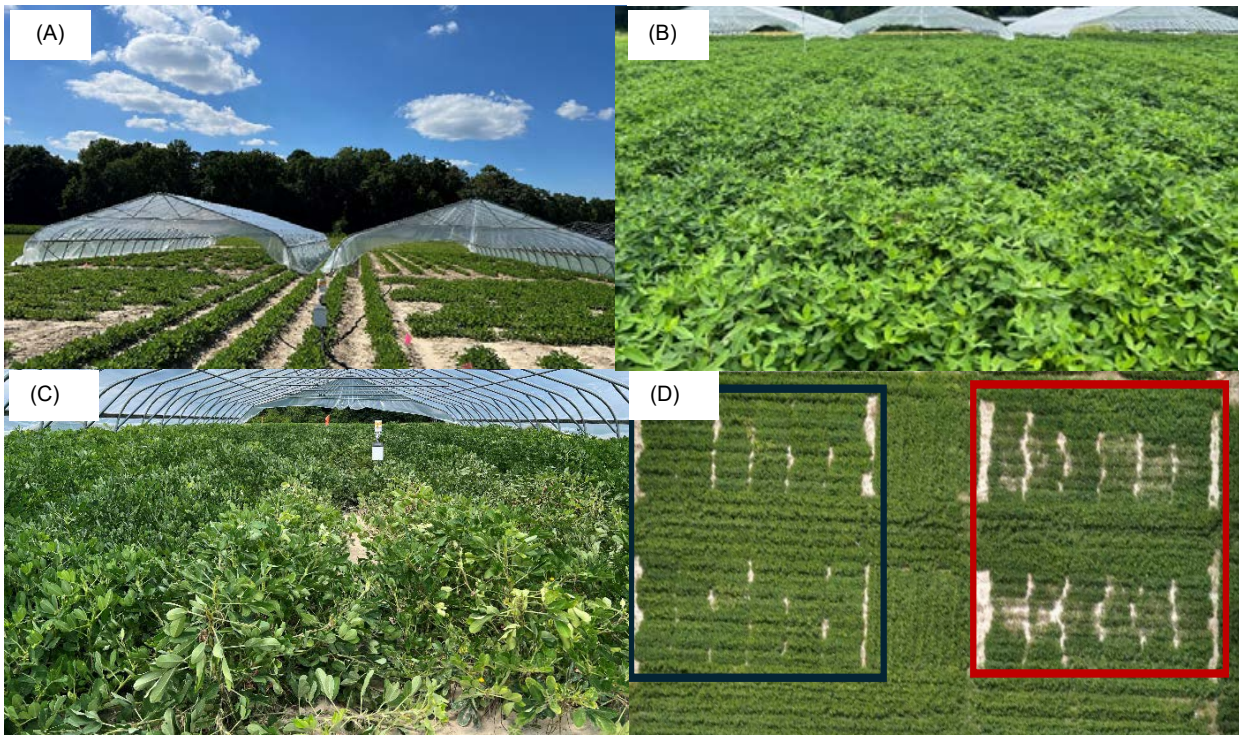

Figure 1. Trial setup consisting of heat and drought-stressed (HS+DS) plots under rainout shelters (A), and open-air rainfed plots (B). A detailed picture of HS+DS plots (C). An aerial image of plots 70 days after stress treatment taken on September 9th, 2024 (D). The black border block refers to rainfed plots and the red border block refers to HS+DS plots.

Table 1. 2024 Peanut HS+DS Trial Overview

Category	Details
Location	Tidewater Agricultural Research and Extension Center, Suffolk, VA
Trial Duration	17th May – 7th October 2024
Genotypes Tested	6 Virginia Tech and University of Florida (VTUF) breeding lines - 13x101-4-5-2-1-B - 13x101-4-5-3-1-B - 13x101-4-9-1-1-B - 14x009-1-5-1-1 - 14x039-1-3-1-1 - 14x085-2-10-1-1 5 Commercial Cultivars - Bailey II - Emery - Sullivan - NC- 20 - Walton 1 Runner Check - PI478818
Stress Setup	**Rainfed Group:** Open plots (control) (Figure 1A, B, D). **HS+DS Group:** Rainout shelters blocked rainfall for 70 days (July 17th – September 9th) (Figure 1A, C, D).
Micro-Climate Monitoring	Sensors tracked - Soil moisture - Air temperature - Soil temperature - Relative humidity
Harvest	7th October 2024 (144 days after planting).
Yield Calculation	Adjusted to 7% moisture: $Yield\ \left(\frac{lbs}{acre}\right) = \frac{\text{Pod weight (kg)*10000 } m^2 \text{ *0.892179}}{\text{Plot area } (m^2)}$
Post-Harvest Grading	Conducted by Virginia Department of Agriculture and Consumer Services. Grades Tracked: - Fancy pods (%) - Extra-large kernels (ELK, %) - Sound mature kernels (SMK, %) - Sound splits (SS, %) - Total sound mature kernels (TSMK = SMK + SS, %)

Key Notes from trial overview (Table 1):

- **Stress Timing**: HS+DS applied during critical flowering/pod-fill stages.
- **Data Collection**: Sensor-based monitoring ensured precise environmental tracking (Figure 2).
- **Grade Metrics**: Focused on market-critical traits (Fancy, ELK, TSMK) for Virginia-type peanuts.

Weather during growing season

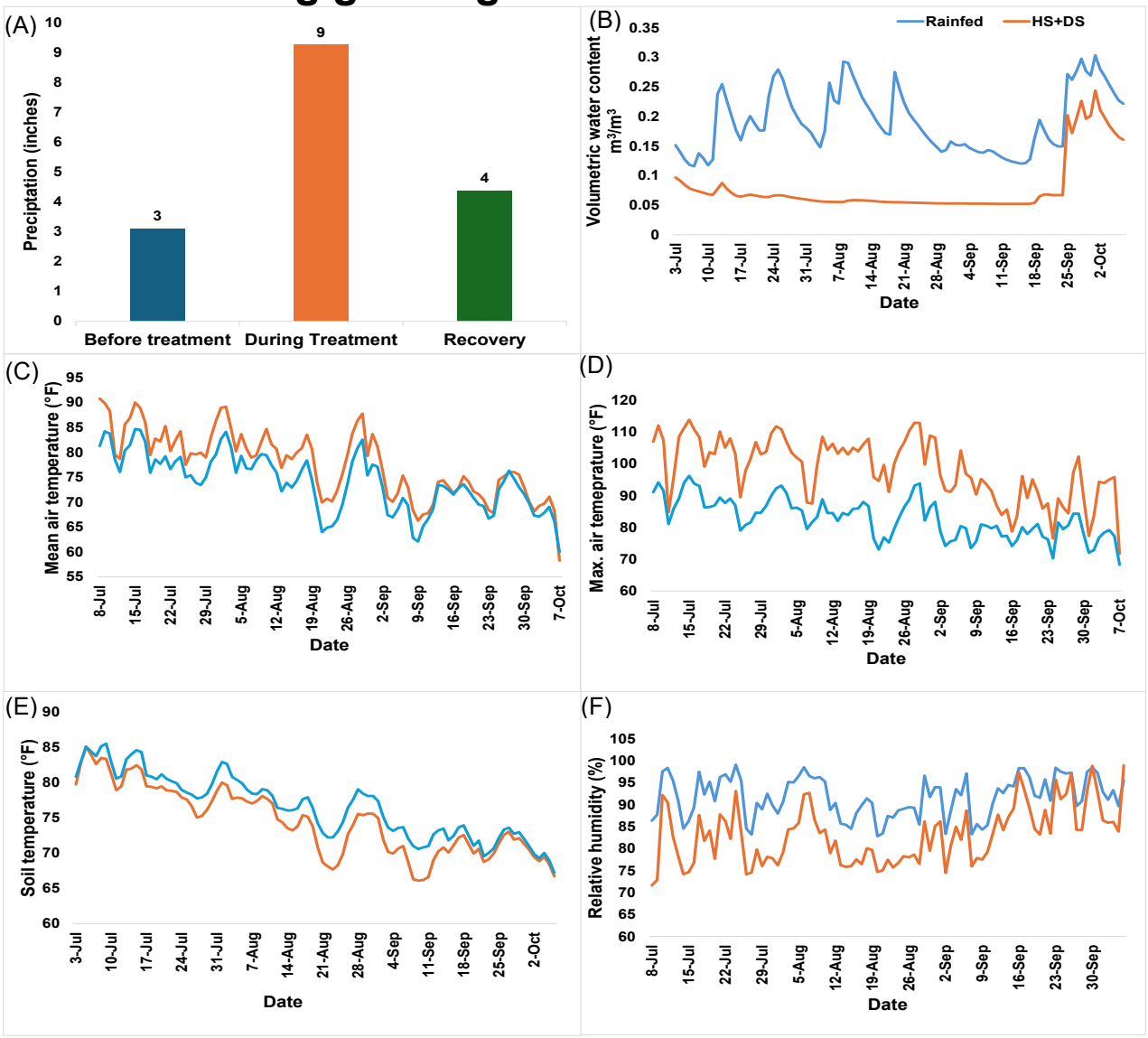

Figure 2. Weather data including precipitation (A), soil volumetric water content monitored at ~7-inch depth (B), mean air temperature (C), maximum air temperature (D), soil temperature (E), and relative humidity (F).

Table 2. Weather parameters and their impact on peanut performance

Parameter	Implications
Rainfall	Stressed plots received 52% less rain—mimicking severe drought conditions (Figure 2A).
Soil Moisture	60% less soil water under stress—critical during pod fill (Figure 2B).
Avg Daily Air Temperature	4°F increase in daily temperature stressed plants during flowering (Figure 2C).
Maximum Daily Air Temperature	100°F spikes during pod fill shrank kernels and reduced grades (Figure 2D).
Soil Temperature	Heat stress came from air, not soil—so focus should be on canopy cooling (Figure 2E).
Relative Humidity	Drier air increased water loss from the leaves (Figure 2F).

How Yield and Grade Fared Across Treatments

Table 3. Yield and grade performance of peanut genotypes under rainfed, heat and drought-stressed conditions

Genotype	Treatment	Yield (lbs/ac)		Fancy (%)		ELK (%)		SMK (%)		TSMK (%)		$/ac	
13x101-4-5-2-1-B	Rainfed	5244	bc	87	a-e	49.3	ab	66	a	67.8	a	1494.6	bc
	HS+DS	3067	ef	84	b-e	36.3	c-f	51	b-d	52.3	bc	874.2	ef
13x101-4-5-3-1-B	Rainfed	5937	a-c	80.5	b-e	47.5	a-c	64	a	66	a	1692.0	a-c
	HS+DS	296	ef	79.5	c-f	31.8	d-g	46	d	48	c	846.0	ef
13x101-4-9-1-1-B	Rainfed	6234	ab	84.3	b-e	49	ab	65	a	67.8	a	1776.5	ab
	HS+DS	1979	f	84.3	b-e	28.5	e-g	45.8	d	46.3	c	564.0	f
14x009-1-5-1-1	Rainfed	7322	a	92.3	a	49.8	ab	68	a	69.25	a	2086.7	a
	HS+DS	3299	d-f	84.7	a-e	29.3	d-g	45.7	d	47	c	940.1	d-f
14x039-1-3-1-1	Rainfed	6333	ab	82	b-e	50.5	ab	63.5	a	66	a	1804.7	ab
	HS+DS	2301	f	75.7	e-g	22	g	42	d	42.7	c	655.9	f
14x085-2-10-1-1	Rainfed	6234	ab	84.3	b-e	39.8	b-f	66	a	66.8	a	1776.5	ab
	HS+DS	2168	f	72.3	fg	27.5	fg	50.8	b-d	52	bc	617.9	f
Bailey II	Rainfed	5739	a-c	86	a-e	50	ab	66	a	67.8	a	1635.6	a-c
	HS+DS	2573	ef	83.5	b-e	35	d-g	50.5	b-d	51.5	bc	733.2	ef
Emery	Rainfed	4354	c-e	81.8	b-e	53	a	68	a	69.5	a	1240.8	c-e
	HS+DS	2293	f	81.7	b-e	32.7	d-g	49.7	b-d	50.7	bc	653.5	f
NC-20	Rainfed	5046	b-d	88	a-e	40.5	b-f	60.5	ab	64.3	a	1438.2	b-d
	HS+DS	3265	d-f	88.3	a-e	27.8	fg	46.8	cd	48.3	c	930.6	d-f
Sullivan	Rainfed	5739	a-c	83.5	b-e	47.5	a-c	65.5	a	67.8	a	1635.6	a-c
	HS+DS	3067	ef	78.3	d-f	32.8	d-g	46.8	cd	48	c	874.2	ef
Walton	Rainfed	5244	bc	70.3	g	41.25	a-d	65.3	a	67.5	a	1494.6	bc
	HS+DS	2771	ef	78.3	d-f	32	d-g	49.5	b-d	50.3	bc	789.6	ef
PI478818	Rainfed	5145	bc	15.5	h	27.5	fg	66.3	a	70	a	1466.4	bc
	HS+DS	2968	ef	14.8	h	28.8	e-g	58	a-c	61	ab	846.0	ef
Overall treatment means	Rainfed	5714	a	77.7	a	45.5	a	65.3	a	67.5	a	1628.5	a
	HS+DS	2727	b	75.3	b	30.5	b	48.7	b	50	b	777.1	b
Stress Treatment (T)		***		*		***		***		***		***	
Genotype (G)		ns		***		*		ns		ns		ns	
T X G		ns		ns		ns		ns		ns		ns	

Means sharing the same letter(s) are not statistically different, at P=0.05 based on Fisher's LSD test. *, **, *** indicate the significant treatment effects at $p < 0.05$, $p < 0.01$, $p < 0.001$ respectively and ns indicates non-significant variation across treatments. ELK-Extra-large kernel, SMK-Sound mature kernel, SS-Sound splits, TSMK- Total sound mature kernel. $/ac=$/acre was calculated based on the year 2024 price of $0.285/lb. (source: Billy Gwaltney, personal communication).

Percentage Declines in Yield and Grade Under Stress

To understand the impact of the reduction due to stress (Table 2 and Figure 2), we calculated the percentage reduction under HS+DS compared to the rainfed conditions using the following equation:

$$\text{Percentage reduction} = \left[\frac{(Value\ under\ HS + DS - Value\ under\ rainfed)}{Value\ under\ rainfed}\right] * 100$$

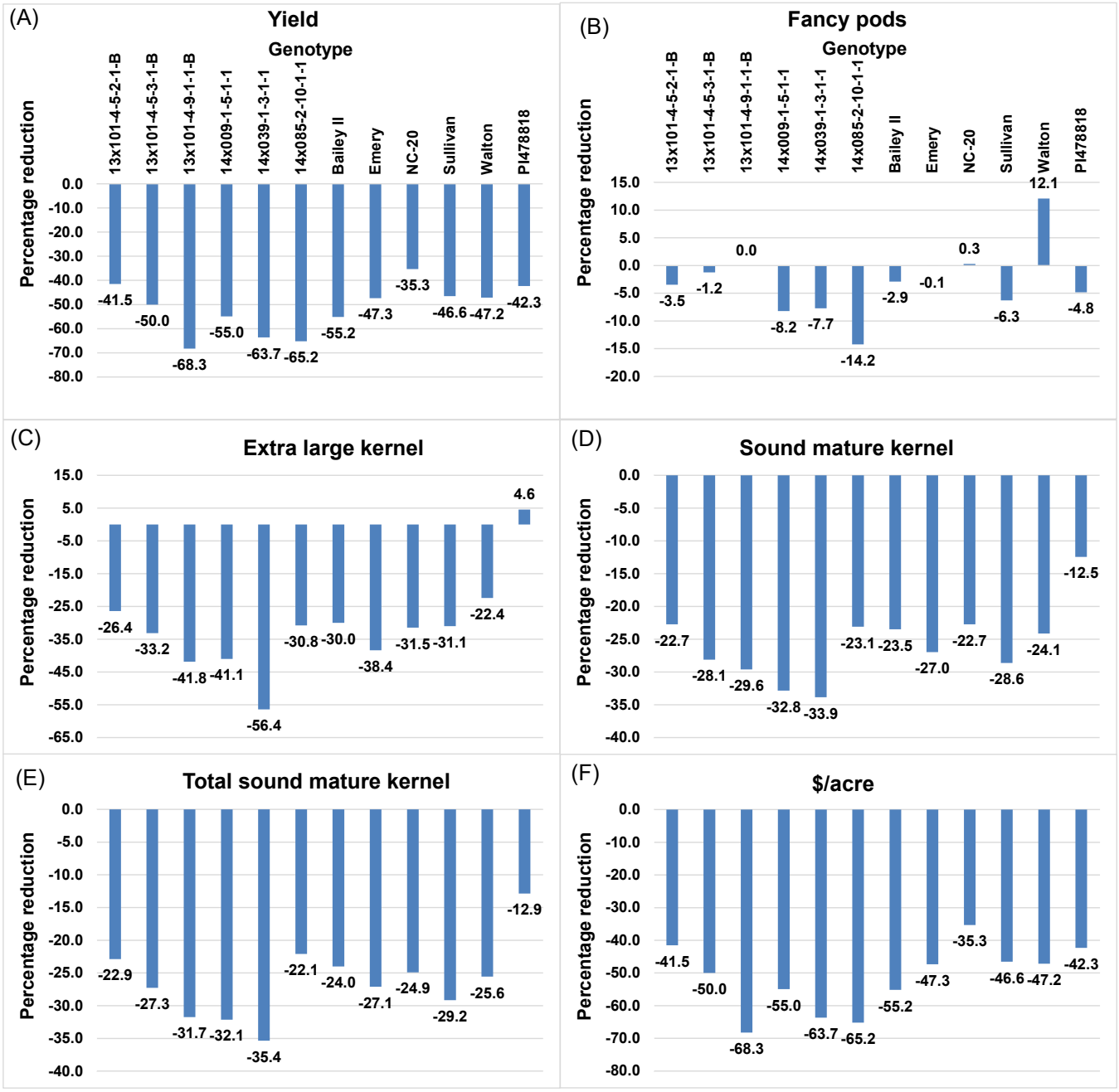

Figure 3. Percentage reduction in yield (A), fancy pod (B), extra-large kernel (C), sound mature kernel (D), total sound mature kernel (E), and economic returns (F) under HS+DS compared to rainfed conditions.

Heat and Drought: How They Hurt Peanut Profits

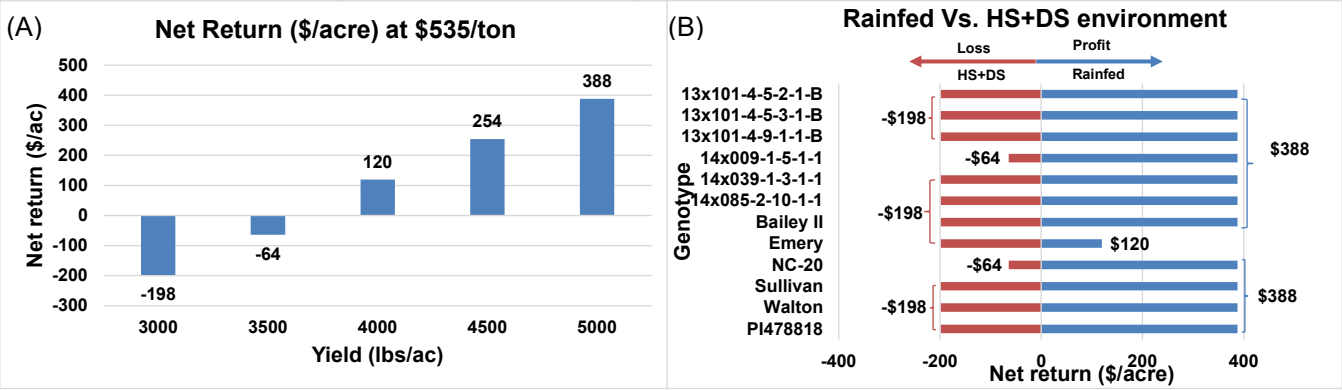

Figure 4. Return to land, overhead, and management @ net return of 535$/ton with assumed total production cost of 1000$/ac (Source: Situation and Outlook by Jeffrey H. Dorfman, Professor and Extension Economist, Department of Agricultural and Resource Economics, NCSU) (A) and predicted net returns ($/ac) on cultivar basis across rainfed vs. HS+DS environment (B).

Key Findings at a Glance

Table 4. Insights into yield, grade, and net returns

Yield Insights	Grade Insights	Net Returns Insights
HS+DS reduced yields by **~40–50%** compared to rainfed conditions (**5,714 lbs/ac → 2727 lbs/ac**) (Table 3, Figure 3A).	HS+DS caused a **33% decline** in ELK, critical for premium pricing (Figure 3C).	Net returns dropped from **+388 $/acre** (rainfed) to **-198 $/acre** (HS+DS) for most genotypes (Figure 4).
Breeding line **14x009-1-5-1-1** achieved the highest yield under rainfed conditions (Table 3).	Total sound mature kernels (TSMK) fell by **26%** under stress, directly lowering market value (Figure 3E).	**NC-20** and **14x009-1-5-1-1** minimized losses (**-64 $/acre**) compared to other varieties **(-198 $/acre**) (Figure 4).
NC-20 and **14x009-1-5-1-1** maintained relatively higher yields under HS+DS (**3,265–3,299** lbs/ac) than other varieties (Table 3).	Variety **Walton** experienced increased fancy pod percentage under stress, suggesting trait-specific resilience (Figure 3B).	HS+DS turned all genotypes into net losses.
Lines **13x101-4-9-1-1-B** and **14x039-1-3-1-1** lost 65–68% yield under HS+DS (Figure 3A).	Commercial cultivars (**Bailey II**) retained better grade stability than most breeding lines under stress (Table 1, Figure 3 B-E).	At $1,000/acre production costs, only **NC-20** and **14x009-1-5-1-1** approached near breakeven under stress (Figure 4).
Yield losses were most severe due to long-term HS+DS during **flowering/pod-fill** (July–September).	Lower ELK and TSMK under HS+DS reduced profitability by **~$500/acre** for sensitive genotypes (Figure 3F).	Lower grades (smaller kernels, fewer fancy pods) reduced price premiums, amplifying financial losses.

Conclusions and Future Directions

Based on the observations from Tables 3 and 4, commercial cultivars generally maintained better grade quality under stress than breeding lines, though the latter excelled in rainfed conditions. These findings highlight the need for breeding programs to integrate stress resilience without compromising yield or grade. Repeated trials in 2025 will validate these results, guiding the development of climate-resilient peanuts to protect Virginia's agricultural economy.

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References

Balota, Maria. 2020. "Rainout shelter-induced water deficit negatively impacts peanut yield and quality in a sub-humid environment". *Peanut Science* 47(2):54-65. Balota | Rainout Shelter-Induced Water Deficit Negatively Impacts Peanut Yield and Quality in a Sub-Humid Environment | Peanut Science

Balota, Maria. 2012. "Effects of Drought and Heat on Peanut (*Arachis hypogaea* L.). Production." . https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/AREC/AREC-27/AREC-27NP-pdf.pdf

Puppala, Naveen, Spurthi N. Nayak, Alvaro Sanz-Saez, Charles Chen, Mura Jyostna Devi, Nivedita Nivedita, Yin Bao, et al. 2023. "Sustaining Yield and Nutritional Quality of Peanuts in Harsh Environments: Physiological and Molecular Basis of Drought and Heat Stress Tolerance." *Frontiers in Genetics* 14 (March). https://doi.org/10.3389/fgene.2023.1121462

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