

Supplementary Material

Allelochemicals extract of star fruit (*Averrhoa carambola* L.) modulates wheat growth through alterations in anatomical architecture

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Table S1. Suppl. Growth, yield and photosynthetic attributes of wheat lines treated with leaf extract of star-fruit plant (*Averrhoa carambola* L.)

Characteristics	Levels	Line-3094	Line-7076	Line-A2011	F-ratio
Morphological traits					
Number of leaves per plant	0%	9.9±0.3a	13.8±0.5a	11.9±0.3a	4.5*
	15%	8.6±0.1a	6.7±0.1b	10.4±0.2a	
	30%	5.9±0.2b	6.4±0.1b	8.8±0.2b	
Shoot fresh weight (g plant ⁻¹)	0%	27.7±0.9c	24.3±0.7c	28.8±1.5a	4.3*
	15%	38.6±1.2a	37.5±1.6a	27.4±0.9a	
	30%	34.4±0.6b	30.0±0.3b	27.1±0.9a	
Shoot dry weight (g plant ⁻¹)	0%	10.7±0.2b	5.8±0.1b	5.3±0.1a	5.9*
	15%	20.3±0.7a	10.5±0.2a	5.7±0.1a	
	30%	7.9±0.2c	12.1±0.1a	5.8±0.1a	
Root fresh weight (g plant ⁻¹)	0%	5.8±0.1a	7.4±0.1a	4.3±0.6ab	4.6*
	15%	3.2±0.1b	3.5±0.1b	3.5±0.1b	
	30%	2.8±0.4c	2.6±0.1b	5.7±0.1a	
Root dry weight (g plant ⁻¹)	0%	2.1±0.1a	2.1±0.1a	1.4±0.1a	6.0*
	15%	0.8±0.1b	1.3±0.1b	1.3±0.1a	
	30%	0.3±0.1b	0.6±0.1c	1.2±0.1a	
100-grain weight (g)	0%	3.4±0.2a	2.3±0.1b	2.5±0.1a	8.2**
	15%	3.1±0.2a	3.2±0.3a	2.6±0.1a	
	30%	3.2±0.2a	2.4±0.1b	1.7±0.1b	
Yields per plant (g plant ⁻¹)	0%	5.9±0.1a	6.1±0.1a	7.1±0.1a	6.8*
	15%	6.2±0.3a	3.8±0.1b	8.3±0.3a	
	30%	3.1±0.3b	2.4±0.1c	2.7±0.1b	
Chlorophyll pigments					
Chlorophyll <i>a</i> (mg g ⁻¹ f.w.)	0%	2.3±0.2a	1.3±0.1b	0.9±0.1b	7.8*
	15%	1.6±0.2b	1.2±0.1b	0.7±0.1b	
	30%	1.3±0.1b	2.3±0.2a	1.5±0.2a	
Chlorophyll <i>b</i> (mg g ⁻¹ f.w.)	0%	0.5±0.02a	0.3±0.01a	0.3±0.01b	5.0*
	15%	0.3±0.02a	0.1±0.01a	0.8±0.02a	
	30%	0.2±0.01a	0.1±0.01a	0.2±0.01b	

Means sharing similar letters are statistically not significant at LSD = 5%.

* = significant at P > 0.05, ** = significant at P > 0.01, *** = significant at P > 0.001, NS = statistically not significant

Table S2. Suppl. Root anatomical attributes of wheat lines treated with leaf extract of star-fruit plant (*Averrhoa carambola* L.)

Characteristics	Levels	Line-3094	Line-7076	Line-A2011	F-ratio
Root radius (μm)	0%	1473.0 \pm 10.5c	1526.9 \pm 10.6a	1672.9 \pm 10.5a	19.1***
	15%	1654.7 \pm 10.5a	1338.3 \pm 27.5b	1227.2 \pm 10.5b	
	30%	1599.8 \pm 10.5b	810.2 \pm 10.5c	929.7 \pm 10.6c	
Epidermal thickness (μm)	0%	69.2 \pm 5.3b	91.5 \pm 10.6c	55.1 \pm 7.7c	8.9**
	15%	115.6 \pm 11.0a	109.0 \pm 10.1b	91.5 \pm 10.5a	
	30%	110.2 \pm 10.5a	155.1 \pm 7.7a	69.2 \pm 5.3b	
Sclerenchyma thickness (μm)	0%	254.4 \pm 10.1b	291.9 \pm 10.5a	292.5 \pm 11.0b	6.5*
	15%	201.1 \pm 10.5c	252.6 \pm 21.0b	236.8 \pm 10.6c	
	30%	382.8 \pm 10.5a	159.9 \pm 10.1c	402.5 \pm 18.0a	
Cortical region thickness (μm)	0%	501.3 \pm 10.1c	436.4 \pm 11.0a	483.0 \pm 15.0a	13.4**
	15%	547.4 \pm 10.5b	405.3 \pm 10.6b	389.7 \pm 7.0b	
	30%	571.9 \pm 10.5a	320.8 \pm 11.1c	147.4 \pm 5.0c	
Cortical cell area (μm^2)	0%	211.6 \pm 21.1a	229.6 \pm 21.1b	283.8 \pm 23.5a	7.8*
	15%	194.2 \pm 13.6b	242.5 \pm 20.9a	208.5 \pm 20.9b	
	30%	210.3 \pm 20.1a	134.9 \pm 13.0c	187.7 \pm 22.4c	
Endodermis thickness (μm)	0%	53.9 \pm 9.6a	55.1 \pm 7.7b	53.9 \pm 9.6b	6.8*
	15%	53.9 \pm 9.6a	92.6 \pm 11.0a	73.3 \pm 10.6a	
	30%	55.1 \pm 7.7a	53.9 \pm 9.6b	55.1 \pm 7.7b	
Metaxylem area (μm^2)	0%	269.8 \pm 26.8a	210.3 \pm 20.1b	176.1 \pm 18.5b	7.9**
	15%	53.8 \pm 10.3c	245.0 \pm 21.8a	245.0 \pm 21.8a	
	30%	214.9 \pm 13.0b	58.1 \pm 26.0c	54.1 \pm 12.2c	
Pith cell area (μm^2)	0%	37.5 \pm 8.7b	53.6 \pm 4.7a	37.5 \pm 8.7a	9.7**
	15%	43.3 \pm 10.3a	32.4 \pm 11.2b	24.6 \pm 4.9b	
	30%	37.5 \pm 8.7b	23.8 \pm 3.7c	23.8 \pm 3.7b	
Pith area (μm^2)	0%	376.1 \pm 19.2b	376.1 \pm 19.2a	294.7 \pm 15.7b	12.9***
	15%	408.8 \pm 24.7a	261.5 \pm 14.3b	315.8 \pm 20.0a	
	30%	176.4 \pm 15.2c	134.9 \pm 10.1c	143.7 \pm 11.7c	

Means sharing similar letters are statistically not significant at LSD = 5%

* = significant at $P > 0.05$, ** = significant at $P > 0.01$, *** = significant at $P > 0.001$

Table S3. Suppl. Stem anatomical attributes of wheat lines treated with leaf extract of star-fruit plant (*Averrhoa carambola* L.)

Characteristics	Levels	Line-3094	Line-7076	Line-A2011	F-ratio
Stem cellular region thickness (μm)	0%	1636.5 \pm 10.1b	2653.4 \pm 10.6b	1510.8 \pm 10.9c	22.7***
	15%	1801.0 \pm 10.9a	2819.3 \pm 10.9a	1819.3 \pm 10.9a	
	30%	1819.3 \pm 10.5a	1627.8 \pm 10.8c	1737.0 \pm 10.8b	
Epidermal thickness (μm)	0%	55.1 \pm 10.6b	55.1 \pm 10.6a	55.1 \pm 7.7a	9.3**
	15%	72.7 \pm 10.5a	55.1 \pm 7.7a	38.2 \pm 10.5b	
	30%	38.2 \pm 10.5c	38.2 \pm 10.5b	55.1 \pm 10.6a	
Chlorenchymatous area (μm^2)	0%	398.5 \pm 22.1a	Absent	Absent	10.9**
	15%	177.2 \pm 14.0c	Absent	Absent	
	30%	304.1 \pm 10.7b	102.4 \pm 9.2a	Absent	
Sclerenchyma thickness (μm)	0%	402.2 \pm 11.1b	494.2 \pm 10.5a	383.4 \pm 9.8a	13.6***
	15%	328.9 \pm 10.5c	438.5 \pm 11.0b	238.0 \pm 10.5b	
	30%	555.9 \pm 21.0a	265.1 \pm 10.2c	383.4 \pm 10.3a	
Cortical cell area (μm^2)	0%	247.6 \pm 13.7b	311.6 \pm 12.9a	371.3 \pm 12.0a	7.8**
	15%	418.7 \pm 17.4a	270.8 \pm 12.5b	363.1 \pm 12.5a	
	30%	226.0 \pm 21.2c	273.0 \pm 11.5b	177.2 \pm 9.8b	
Vascular bundle area (μm^2)	0%	862.9 \pm 9.9b	428.7 \pm 6.7b	764.1 \pm 4.5b	15.8***
	15%	1039.9 \pm 12.3a	764.1 \pm 16.5a	1036.7 \pm 9.2a	
	30%	624.7 \pm 11.1c	430.1 \pm 13.4b	1024.7 \pm 9.2a	
Vascular bundle number	0%	32.5 \pm 1.3b	24.8 \pm 0.9c	48.9 \pm 0.9b	6.9*
	15%	31.7 \pm 1.3b	36.3 \pm 1.5b	28.2 \pm 0.8c	
	30%	64.3 \pm 1.1a	49.9 \pm 1.3a	71.1 \pm 1.6a	
Metaxylem area (μm^2)	0%	45.6 \pm 16.5b	102.7 \pm 16.5b	74.2 \pm 17.3c	8.7**
	15%	74.2 \pm 17.3a	155.1 \pm 14.4a	132.2 \pm 17.2a	
	30%	74.2 \pm 17.3a	155.1 \pm 14.4a	99.9 \pm 15.9b	
Phloem area (μm^2)	0%	232.2 \pm 17.2b	174.2 \pm 17.3c	246.4 \pm 17.2a	12.1***
	15%	274.0 \pm 16.5a	232.2 \pm 17.2a	246.4 \pm 17.2a	
	30%	174.2 \pm 17.3c	202.7 \pm 16.5b	232.2 \pm 17.2b	

Means sharing similar letters are statistically not significant at LSD = 5%

* = significant at $P > 0.05$, ** = significant at $P > 0.01$, *** = significant at $P > 0.001$

Table S4. Suppl. Leaf anatomical attributes of wheat lines treated with leaf extract of star-fruit plant (*Averrhoa carambola* L.)

Characteristics	Levels	Line-3094	Line-7076	Line-A2011	F-ratio
Midrib thickness (μm)	0%	3094.8 \pm 31.0a	3473.6 \pm 26.5a	3276.4 \pm 33.7a	35.6***
	15%	2765.4 \pm 27.0b	2183.0 \pm 22.5b	2746.5 \pm 33.5b	
	30%	1001.4 \pm 22.5c	1165.1 \pm 19.9c	1255.9 \pm 21.9c	
Lamina thickness (μm)	0%	746.8 \pm 11.6a	937.9 \pm 9.8a	474.8 \pm 11.0a	8.3**
	15%	583.5 \pm 4.5b	201.7 \pm 5.6b	383.4 \pm 6.7b	
	30%	414.3 \pm 5.6c	223.5 \pm 4.3b	205.3 \pm 4.1c	
Parenchymatous cell area (μm^2)	0%	371.3 \pm 12.0a	274.0 \pm 12.5a	274.0 \pm 12.5a	9.3**
	15%	254.4 \pm 10.2b	274.0 \pm 12.5a	154.4 \pm 10.2b	
	30%	225.3 \pm 6.9c	115.4 \pm 5.6b	115.4 \pm 5.6c	
Sclerenchyma thickness (μm)	0%	332.9 \pm 8.5a	247.6 \pm 17.6a	326.8 \pm 16.8a	12.9***
	15%	319.5 \pm 14.1ab	146.9 \pm 16.8b	177.2 \pm 18.4b	
	30%	202.1 \pm 5.3b	104.4 \pm 5.2c	73.2 \pm 5.8c	
Vascular bundle area (μm^2)	0%	973.8 \pm 8.0a	420.5 \pm 18.4a	536.9 \pm 15.6a	16.7***
	15%	371.3 \pm 12.0b	246.3 \pm 12.7b	286.6 \pm 11.5b	
	30%	114.9 \pm 13.0c	148.0 \pm 17.6c	139.0 \pm 9.0c	
Metaxylem area (μm^2)	0%	54.4 \pm 10.2a	39.0 \pm 9.0a	39.0 \pm 9.0a	5.6*
	15%	15.4 \pm 5.6b	25.3 \pm 6.9b	25.3 \pm 6.9b	
	30%	7.9 \pm 3.9bc	15.4 \pm 5.6c	15.4 \pm 5.6c	
Phloem area (μm^2)	0%	247.6 \pm 22.8a	114.9 \pm 13.0b	120.5 \pm 15.9b	8.5**
	15%	177.2 \pm 18.4b	146.9 \pm 16.8a	146.9 \pm 16.8a	
	30%	25.3 \pm 6.9c	39.0 \pm 9.0c	39.0 \pm 9.0c	
Stomatal density per mm^2	0%	65.1 \pm 0.1a	49.1 \pm 0.1b	49.1 \pm 0.06a	6.2*
	15%	41.1 \pm 0.06c	55.1 \pm 0.06a	43.1 \pm 0.06b	
	30%	56.1 \pm 0.06b	43.1 \pm 0.06c	41.1 \pm 0.06b	
Stomatal area (μm)	0%	391.6 \pm 23.9a	243.5 \pm 19.1c	390.5 \pm 14.9a	19.1***
	15%	325.1 \pm 32.8b	419.2 \pm 33.9a	233.9 \pm 17.9c	
	30%	217.1 \pm 22.2c	367.4 \pm 23.8b	304.1 \pm 21.9b	

Means sharing similar letters are statistically not significant at LSD = 5%

* = significant at $P > 0.05$, ** = significant at $P > 0.01$, *** = significant at $P > 0.001$