Shade, Establishment Method and Varietal Effects on Rhizome Yield and Curcumin Content in Turmeric in Alabama

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Introduction

Turmeric (*Curcuma longa*) is a spice containing curcumin, which has potential for treating cancer and Alzheimer's disease. Cultivation of turmeric in the United States would allow greater quality assurance and reduced transportation costs compared to importation from Asia. The hot, humid summers in southeastern U.S. are suitable for growing turmeric but the hot season is short relative to the tropics. Research on cultivation practices for this region is lacking. Preliminary studies showed that starting plants early on heat accelerated sprouting and doubled yield compared to planting in the field. In mid-summer, plants in full sun wilted, suggesting that shade might be beneficial. Large differences in curcumin concentration among accessions were observed in preliminary unreplicated measurements. High curcumin concentration is key to industry acceptance of U.S.-grown turmeric.

Objectives

Assess effects of shade, early sprouting of rhizomes over heat, and variety on rhizome yield and curcumin concentration and yield.

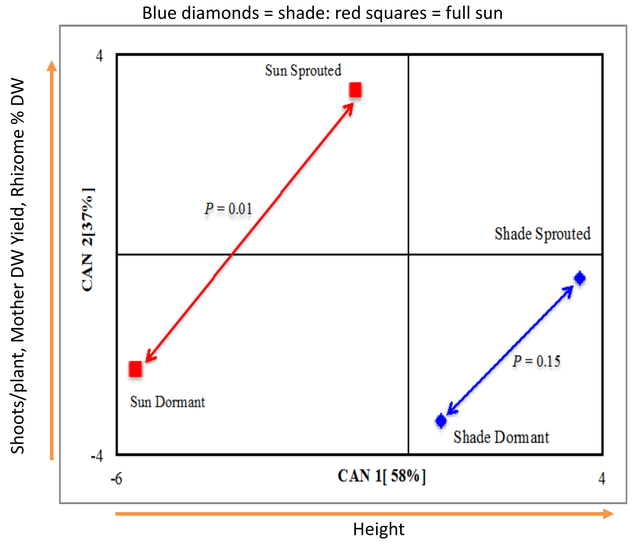
Materials and Methods

Location: Auburn, AL (32.59° N, 85.49° W, 200 m elevation), Marlboro Series (fine, kaolinitic, thermic Typic Paleudults)
Shade: 40 % shade vs full sun
Establishment: on heat pads (27 C) April 6, 2012, transplanted to field May 23 vs unsprouted rhizomes planted in field May 23.
Varieties: 3 acc. *C. longa* (CL2, CL3, CL5), 1 acc. tentatively *C. amada* (Ca1)
Design: Limited by resources. RCB (r=2) within each shade type; split plot – establishment in main plot, variety in subplot
Curcumin analysis: ground dry turmeric rhizome extracted in 90 % ethanol, analyzed for curcumin, demthoxycurcumin and bisdemethoxycurcumin using HPLC.
Harvest: Rhizomes harvested after killing frost, washed and separated into mother and lateral rhizomes. Samples sliced and dried at 42 C.
Data analysis: Canonical discriminant analysis (CDA) in SAS® PROC CANDISC, pairwise combinations of treatment factors shade, establishment and cultivar as class variable. Individual response variables analyzed using mixed models methodology as implemented in SAS® PROC MIXED. Block(Shade) and Establishment Method x Block(Shade) were the random effect in addition to the residual variance. Shade, establishment, and variety as well as their interactions were treated as fixed effects.

Results

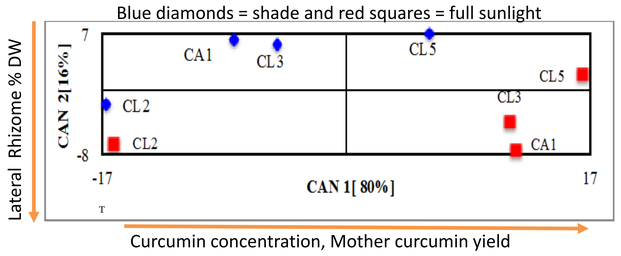
Shade Treatment x Establishment Method

Blue diamonds = shade: red squares = full sun



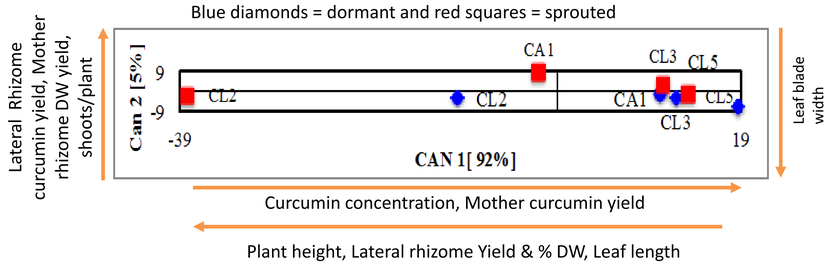
Shade Treatment x Variety

Blue diamonds = shade and red squares = full sunlight



Establishment x Variety

Blue diamonds = dormant and red squares = sprouted



Least squares means for shading treatments, establishment methods and varieties with associated *P*-values from the analysis of variance for turmeric plant height, leaf blade dimensions, shoots per plant, and rhizome dry weight yield.

Effect	Plant height m	Leaf blade length cm	Shoots per plant	Lateral rhizome dry matter %	Lateral rhizome dry weight kg ha^{-1}	Mother rhizome dry matter %	Mother rhizome dry weight kg ha^{-1}	Total Rhizome fresh weight kg ha^{-1}	Total rhizome dry weight kg. ha^{-1}
Shading									
Shade	1.42	66.5	5.8	16.8	2607	21.1	1000	19600	3610
Sun	1.06	53.7	6.9	18.0	2228	21.9	1050	15900	3280
P(Shading)	**0.001**	0.226	0.549	0.358	0.399	0.589	0.783	**0.019**	0.520
Establishment									
D	1.18	59.9	4.3	16.6	1474	21.2	900	12200	2380
H	1.30	60.3	8.4	18.1	3361	21.7	1150	23400	4510
P(Establishment)	**0.002**	0.940	**0.009**	0.104	**<0.001**	0.672	0.171	**0.002**	**0.002**
P(Shade*Establ.)	0.956	0.880	0.801	0.327	0.572	0.949	0.798	0.121	0.757
Variety									
CA1	1.22b	57.0a	7.2a	18.6b	2748b	22.2a	1040a	19000ab	3790ab
CL2	1.45a	67.7a	5.9a	21.7a	4095a	22.9a	990a	23800a	5090a
CL3	1.24b	61.4a	6.4a	17.6b	1794bc	22.3a	1120a	15100b	2920bc
CL5	1.06b	54.1a	5.8a	11.6c	1034c	18.5b	950a	13700b	1980c
P(Variety)	**0.021**	0.088	0.625	**<0.001**	**<0.001**	**0.021**	0.713	**0.004**	**0.002**
P(Shade*Variety)	0.322	0.845	0.806	**0.076**	0.546	0.452	0.396	0.463	0.490
P(Establ*Variety)	0.721	0.927	0.612	**0.016**	0.179	0.169	0.521	0.410	0.393

Means in same column followed by same letter do not differ at $P \le 0.05$

Canonical Discriminant Analysis (CDA): distinctive trends based upon variety, establishment method and +/-shade.
Analysis of variance: **Extending the growing season** increased plant height, shoots per plant, rhizome and curcumin yield and curcumin concentration in lateral rhizomes.
Shade increased plant height and fresh weight of rhizomes. Apparent increases in leaf size and rhizome dry weight were not significant by analysis of variance but contributed to the differences among CDA centroid means for Shade Treatment x Variety classes. Shade decreased curcumin concentration in mother rhizomes, but had little effect on curcumin concentration in lateral rhizomes. An apparent increase in curcumin yield in lateral rhizomes with shade was not significant by analysis of variance but also contributed to differences among centroid means for Shade Treatment x Variety.
Significant differences among **varieties** were observed for plant height, rhizome % dry matter, yield and curcumin concentration and yield.

Least squares means for shading treatments, establishment methods and varieties with associated *P*-values from the analysis of variance for rhizome curcumin content and yield.

Effect	Lateral rhizome curcumin conc.† mg g^{-1}	Mother rhizome curcumin conc.† mg g^{-1}	Lateral rhizome curcumin yield kg ha^{-1}	Mother rhizome curcumin yield kg ha^{-1}	Total rhizome curcumin yield kg ha^{-1}
Shading					
Shade	26.1	28.1	59.2	28.3	87.7
Sun	25.4	39.1	45.0	40.3	85.4
P(Shading)	0.778	**0.072**	0.285	0.202	0.748
Establishment					
D	22.6	33.7	25.4	28.3	54.1
H	28.9	33.6	78.8	40.3	119.0
P(Establishment)	0.094	0.963	**0.087**	**0.009**	**<0.001**
P(Shade*Establ.)	0.580	0.631	0.945	0.081	0.312
Variety					
CA1	31.0a	37.6b	88.9a	38.6a	127.8a
CL2	4.7b	8.0c	20.2c	7.8b	28.0c
CL3	32.0a	39.1b	61.3ab	44.5a	105.8ab
CL5	35.3a	49.7a	38.0bc	46.0a	84.6b
P(Variety)	**<0.001**	**<0.001**	**0.001**	**<0.001**	**<0.001**
P(Shade*Variety)	0.974	**0.006**	0.560	**0.010**	0.181
P(Establ*Variety)	0.370	0.120	**0.041**	**0.047**	**0.011**

†Adjusted to 10 % moisture
Means in same column followed by same letter do not differ at $P \le 0.05$

Conclusions

- Cultivation of turmeric in Alabama is feasible.
- Yields and curcumin content can be enhanced by extending the growing season and by variety selection.
- Shade increased plant height; trend for larger leaves with shade.
- Shade had less effect on yield than anticipated.
- Trend toward greater rhizome yield with shade might test significant with greater precision.

Research needs:

- ways to extend the growing season using heat and high tunnels
- variety selection for earlier maturity and high curcumin
- role of shade on yield and curcumin content.