2021

Effects of Using Low Tunnel and Grafted Plants for Watermelon Production under Low Temperature Stress in Indiana

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Indiana ranks sixth in harvested watermelon acreage in the US. A total of 6,500 acres of watermelons were planted in Indiana in 2019 with a production value of $35 million (USDA, 2020). Use of grafted watermelon plants is effective in controlling fusarium wilt; hybrid squash rootstock (*Cucurbita maxima* × *Cucurbita moschata*) is the most widely used rootstock for watermelons worldwide. A recently developed rootstock 'Carolina Strongback' (*Citrullus lanatus* var. *citroides*) has resistance to both fusarium wilt and root-knot nematode. Watermelons from Indiana typically enter into market around mid-July. To extend the watermelon season and target potentially higher early-market prices, growers may use low tunnels for early-planted watermelon in Indiana.

Materials and Methods

Watermelon cultivar Fascination and pollenizer SP7 were used in the study. Non-grafted plants were grown in a greenhouse at the Southwest Purdue Agricultural Center in Vincennes, IN. Seeds were sown in 50-cell trays on 20 March 2020. Grafted 'Fascination' and SP7 plants were supplied by Tri-Hishtil. They were grafted onto hybrid squash rootstock 'Camelforce' and citron rootstock 'Carolina Strongback'. Grafted plants were grown in 128-cell trays. Grafted plants were placed in the same greenhouse as the non-grafted plants after they arrived on 20 Apr. Both grafted and non-grafted seedlings were transplanted in the field on 24 Apr.

Soil of the experimental field is sandy loam with 1.2% organic matter. Fertilizers at a rate of 300 lb/acre urea (46-0-0), 100 lb/acre potash (0-0-60), 100 lb/acre K-Mag granular (0-0- 22-11-22), 7 lb/acre boron 14.3%, and 10 lb/acre Zinc 10% LS were pre-plant broadcast applied. Plants were grown on raised beds (8-ft center) covered with black plastic mulch. Drip tapes with a 12-inch emitter spacing and a flow rate of 0.22 gpm/100 feet were used for irrigation.

A two-factor factorial design with four replications was used in the study. Low tunnel (LT: with LT and without LT) and grafting were the two factors of interest. The grafting treatments included non-grafted 'Fascination', 'Fascination' grafted onto 'Camelforce' rootstock, and 'Fascination' grafted onto 'Carolina Strongback' rootstock. Pollenizer plants of the same rootstock (or non-grafted) as the seedless watermelons were planted for each treatment.

Experimental plots comprised one 40-ft long bed. Seedless watermelons were planted 4 ft apart. A pollenizer plant was planted at every two seedless watermelon plants. The ratio of pollenizer plants to seedless watermelon plants was 1:2. Each experimental plot comprised of 10 seedless watermelon plants and 5 pollenizer plants.

Low tunnels covered with 1 mil perforated row cover were installed using a mechanical transplanter low tunnel layer (Figure 1) on 24 Apr., the same day that seedlings were transplanted. Low tunnels were removed on 25 May. Hobo data loggers were used to measure air temperatures at the height of plant canopy and soil temperatures at 4-inch depth. Temperatures

were measured every 30 minutes. The number of surviving plants was counted on 4, 21, and 26 May. Only data from 26 May were used in the analyses. Vine length was measured on 27 May on three typical plants in each experimental plot. Dead plants were not replanted. Harvest was conducted five times on 15, 24, 30 July and 6, 12 Aug. Watermelons were weighed individually, and separated by marketable and cull fruit.

Statistical analyses were conducted using JMP Pro 14. Tukey's HSD test was used for multiple comparisons.

Results

Air and soil temperatures with and without low tunnels are presented in Figure 2 and 3, respectively. During the period when low tunnel was implemented (24 Apr. to 25 May), minimum air temperatures were below 40 °F on five days. The lowest minimum air temperature was 29.3 °F in the treatment without low tunnels in the morning of 9 May. Temperatures below 32 °F lasted for 5 hours from 2:30 am to 7:30 am. Under low tunnels, the recorded lowest minimum temperature was 33.8 °F on the same day.

Without low tunnels, soil temperatures ranged from 51 °F to 73 °F, and stayed above 60 °F after 14 May. Average soil temperature was 60.2 °F from 24 Apr. to 14 May. Under low tunnels, soil temperatures ranged from 53.3 °F to 87 °F during the same period, with an average soil temperature at 66.5 °F. Maximum air temperatures above 120 °F occurred in 7 days under low tunnels from 24 Apr. to 25 May. The highest maximum air temperature was 129.2 °F under low tunnels, while it was 99.7 °F without low tunnels.

Both low tunnel and grafting, as well as their interaction had significant effects on plant survival rate (Table 1). Under low tunnels, grafted 'Fascination', regardless of rootstocks, had significantly higher survival rate compared to that of non-grafted 'Fascination' (Table 2). Without low tunnels, 'Fascination' grafted onto 'Camelforce' rootstock had higher survival rate compared to 'Carolina Strongback' rootstock, and both were higher than non-grafted 'Fascination'. Using low tunnels increased plant survival rate of grafted plants with 'Carolina Strongback' rootstock, while there were no effects on survival rates of non-grafted plants and grafted plants with 'Camelforce' rootstock. Significant effects of both low tunnel, grafting and their interaction were also observed on vine growth (Table 1). Grafted 'Fascination' with 'Camelforce' rootstock had longer vines compared to grafted plants with 'Carolina Strongback' rootstock, and both grafted treatments had longer vines compared to non-grafted plants (Table 2). Low tunnels significantly increased vine growth regardless of grafting treatments, but the effect was more pronounced on grafted plants than non-grafted plants, mainly because a large percentage of non-grafted plants were already lost.

After low tunnels were removed on 25 May, heat injury was observed on plants under low tunnels. The tips of the vines were yellow and had necrotic leaves (Figure 4). Plants recovered after low tunnels were removed, yellowing leaves became necrotic, and the new growing tips looked healthy.

Significant yield difference was observed among grafting treatments and low tunnel treatments; no interaction was observed (Table 1). Grafted ‘Fascination’ regardless of rootstocks had higher yield than non-grafted ‘Fascination’ (Table 2). No significant yield difference was observed between ‘Camelforce’ and ‘Carolina Strongback’ rootstocks. Using a low tunnel in the first month of the season significantly increased yield. This effect was likely due to higher plant survival rate under low temperature stresses.

Conclusion

Results of the study indicated that grafted seedless watermelon plants can better tolerate cold stress in the early watermelon season compared to non-grafted seedless watermelon plants. Grafted plants with ‘Camelforce’ rootstock had better cold tolerance than plants with ‘Carolina Strongback’ rootstock. While the low tunnel is effective in increasing plant growth in the early watermelon season, the effect of using low tunnels to improve plant survival rate under extreme weather conditions is limited. The level of the temperature stress, and cold tolerance of the plants could affect the effect of using low tunnels. It is also important to note that the low tunnels used in this study can easily raise air temperatures above 120 °F; that may cause heat injury on watermelon plants, especially when the vines touch plastic.

References

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Acknowledgements

The author would like to thank Dean Haseman, Dennis Nowaskie and other Southwest Purdue Agricultural Center staff for helping with the experiment.

Table 1. Analysis of variance of the effects of low tunnels (LT) and grafting (G) on plant survival rate, vine length and yield of seedless watermelon 'Fascination' in the trial conducted in 2020 in Vincennes, IN.

Effect	***P* for plant survival rate**	***P* for plant vine length**	***P* for yield**
LT	0.0001	<.0001	0.0008
G	<.0001	<.0001	<.0001
LT and G interaction	0.0137	<.0001	0.8594

Table 2. Comparisons for plant survival rate, vine length and yield per plot in the trial conducted in 2020 in Vincennes, IN.

Treatment	**Transplant survival rate (%)**		**Vine length (cm)**		**Total Yield per plot (lb)**	
	Low tunnel	Without low tunnel	Low tunnel	Without low tunnel	Low tunnel	Without low tunnel
Non-grafted watermelon	22.5 Ab	5.0 Ac	19.6 Ac	0.8 Bc	110.7 Ab	6.0 Bb
Rootstock 'Camelforce'	100.0 Aa	95.0 Ab	94.2 Aa	38.9 Ba	359.4 Aa	233.6 Ba
Rootstock 'Carolina Strongback'	97.5 Aa	67.5 Ba	63.2 Ab	12.0 Bb	275.1 Aa	172.9 Ba

Means followed by the same lowercase letter with a column, and means followed by the same uppercase letter within a row are not significantly different at $P \leq 0.05$ according to Tukey's HSD test.

Figure 1. Low tunnel covered with 1 mil perforated row cover was installed using a mechanical transplanter low tunnel layer on 24 Apr. 2020.

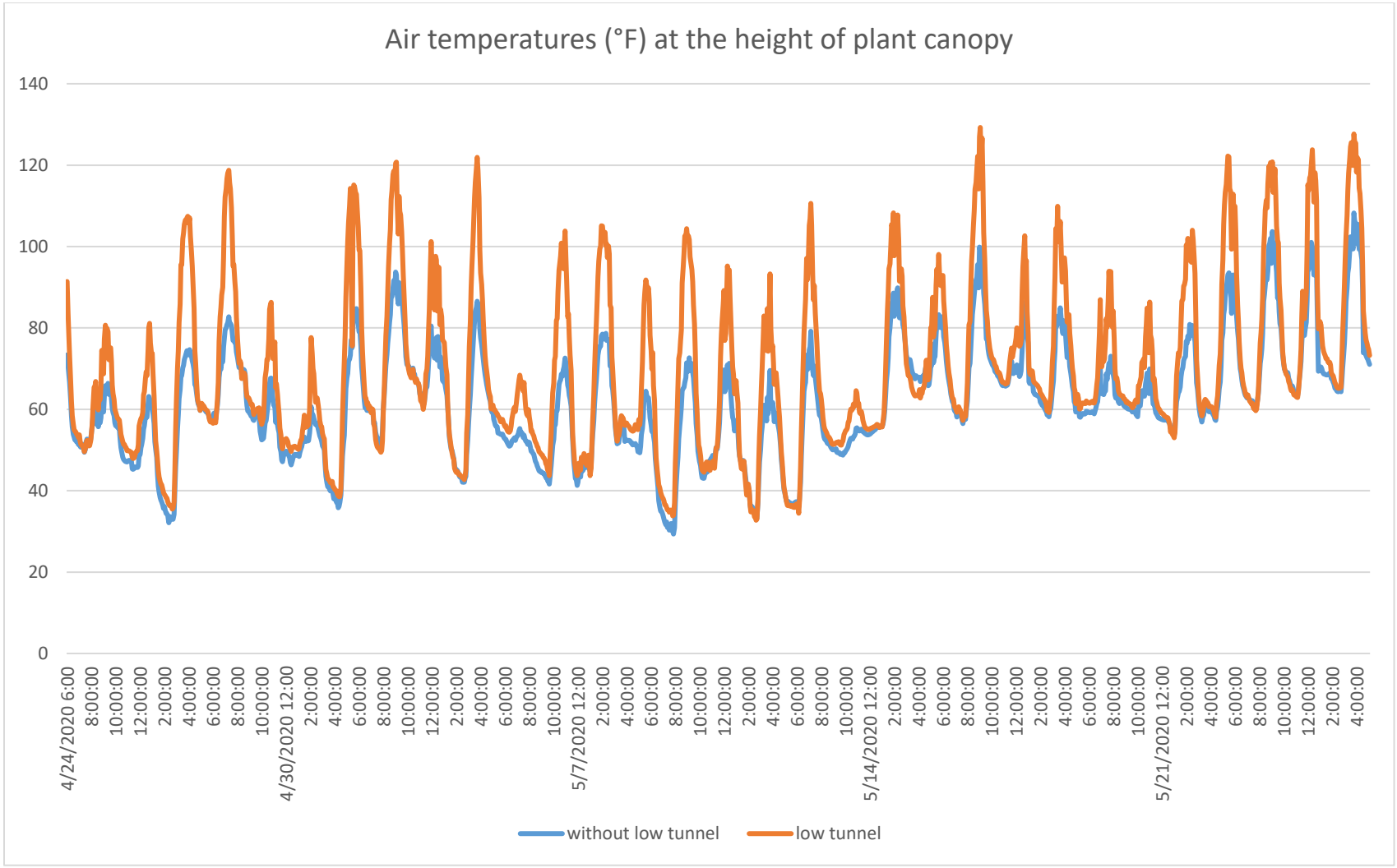

Figure 2. Air temperatures at the height of plant, with and without low tunnels from 24 Apr. to 25 May, 2020 in Vincennes, IN.

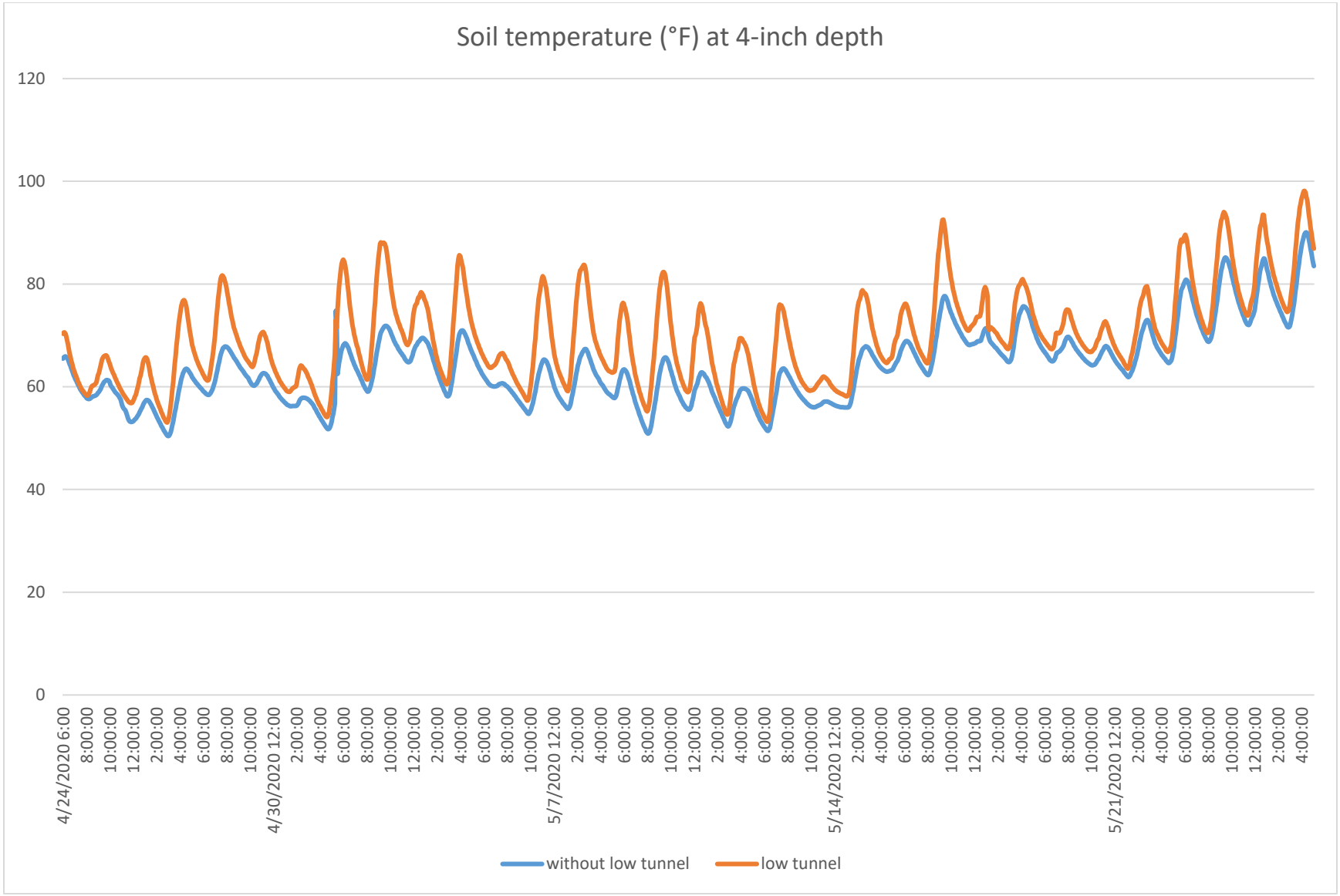

Figure 3. Soil temperatures at 4-inch depth with and without low tunnels from 24 Apr. to 25 May, 2020.

Figure 4. Heat injury on watermelon plants. Left: tips of the vines were yellowing right after low tunnels were removed. Right: plants recovered after a few days.