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USE OF SHADE IN VEGETABLE PRODUCTION: HOT PEPPER

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ABSTRACT. Shades are often used in horticultural production to extend growing season, enhance crop growth, and improve yield. A study was conducted to evatuate the effect of shade on vegetative growth and yield components of hot pepper *(Capsicum annum*, L., var. Scoth Bonnet). Continuous shade under tent fabric (polypropylene mesh) was compared to full sunlight and black plastic mulch was used to control weeds. A complete randomized design was used and the effects of shade were measured at 6 week-intervals using leaf area, plant height, stem diameter, fresh and dry biomass production and their partitioning, and fruit yield components. The tent fabric reduced light by 70% at 0900h, 64% at 1300h, and 87% at 1700h. Leaf area was higher under shade (42.5%) and was maintained up to 18 weeks after transplanting (WAT). Shade resulted in increase plant height and reduced stem diameter by 76.2% and 10%, respectively. Shade also reduced the number of fresh fruit as well as fresh fruit weight by 306 and 210%, respectively. However, shade increased unit fresh fruit weight by 31%. In addition, biomass was reduced by as much as 41.1%. Scotch Bonnet hot peppers grown under shade had increased vegetative growth but decreased fruit production and biomass accumulation. However, fruit size is a critical economic factor aand must be considered in the marketing of Scotch Bonnet.

INTRODUCTION

In Alabama, hot peppers *(Capsicum annum)*, vegetables and small fruits are being viewed as promising economic alternatives for small scale and limited resources farmers (Colette and Wall, 1987). It has always been the view of crop producers that in order to improve crop yields and quality, intensive use of agrichemicals must be practiced. However, higher production costs and environmental degradation associated with such practices are concerns that have been cited to discontinue the practice. To reduce environmental degradation, alternative technologies such as shades are being used in horticultural and other crop production systems to extend growing season, enhance growth, and improve yields (Schou et al., 1978; Wells and Loy, 1985).

It has been shown that crop species vary in their response to row covers or shades and results differ depending on cultivar, types of materials used, and environmental conditions. Wolfe and Rutkowski (1987) have grown vegetables under cover and have consistently produced fruits earlier with increased total yields. Further studies by Wells and Loy (1985) using cucumber have obtained increased yields with the use of row covers, but the effects on earliness and fruit size were variable. Wolfe and Bell (1987) reported that reduction in early yield and fruit size are associated with tomatoes grown under covers and at high temperatures.

Researchers at Tuskegee University and elsewhere in Alabama have noted that row covers were capable of modifying microclimates associated with row covers and shades. Brown et al., (1986) have shown that the use of row covers and plastic mulches increased growth and crop performance of eggplants grown in intercop with mustard greens. Khan et al., (1989; 1996a) have consistently produced watermelons and muskmelons early in Alabama to meet the high demands of Independence (July 4^{th}) holiday. In examining the economic impact of row covers and plastic mulches, Wilson et al. (1987) have shown that both cover and mulches were influential in the earliness and yield of watermelons and muskmelons. Khan et al., (1996b) examined the effects of plastic mulches on sweetpotato production and found that both clear and black plastic significantly improved vine and root production.

In addition to temperature, shade effects of row cover must also be studied. Wien (1990) reported that peppers were susceptible to flower and fruit abscission when subjected to shade which reduced yields. In contrast, Roberts and Anderson (1994) have noted that the marketable yields of bell peppers shaded with spun bonded polypropylene row covers were equal to or greater than those grown using plastic or straw mulches. They also noticed that there was reduced solar injury or "sun burn" of fruits under shade and this was critical to the marketing of pepper. Overall, shade is known to extend the juvenile phase of plant development by prolonged juvenile leaves (Jones, 1995). The objectives of this study were; (1) to determine the patterns of growth, partitioning, and response of "Scotch Bonnet" hot pepper to continuous shade compared to full sunlight; and (2) to evaluate the advantages and disadvantages of special polypropylene mesh fabric, designed for camouflage, on the growth and development of plants.

MATERIALS AND METHODS

This study was conducted in the summer of 1996 at the George Washington Carver Experimental Station, Tuskegee University, Alabama. Eight week-old "Scotch Bonnet" seedlings were transplanted 60 cm apart into rows spaced 1 m apart. Black plastic mulch was used to cover the rows in order to suppress weed growth. Plants were exposed to continuous shading under a special polypropylene mesh fabric (1.6mm x 1.9mm) and were compared to plants that received full sunlight. The soil was a Norfolk loamy sand (fine-loamy, siliceous, thermic, typic paleudult) with a pH of 5.9 and a Cation Exchange Capacity (CEC) less than 4.6 $cmolc.kg^{-1}$. Fertilizer was applied at a rate of 80-60-30 Kg N, P_2O_5, and K_2O per hectare at the time of mulch application. To avoid water deficit, plants were supplied with drip irrigation at a rate of 1.78 liters day^{-1} when needed. The experiment was arranged as a randomized complete block design with four replications.

Three randomly selected hot pepper plants were harvested at 6 week-intervals (6, 12, and 18 weeks after transplanting). At each harvest period, leaf area, plant height, stem diameter, fresh and dry biomass were determined. Leaf area was measures using a LICOR Model 3100 Area meter (LICOR, INC., Lincoln, Nebraska, USA). Dried biomass data were obtained after oven-drying the plant samples at 70° C for 72 hours. Since light intensity was critical to understanding the response of hot peppers to shade, prior to sampling, light radiation data were taken. This was measured above the plant canopy at 0900h, 1300h, 1500h, and 1700h (Central Daylight Time-CDT) using a LICOR Model LI 185 B-LI 185 190SB Quantum Sensor Radiometer (LICOR, Inc., Lincoln, Nebraska, USA).

Mature hot pepper fruits were harvested weekly and both number and fresh fruit weight were recorded. To ascertain the effects of shade and harvest date, data on plant leaf area, plant height, stem diameter, fresh and dry biomass production, stem to leaf ratio, cumulative yield, and yield components were subjected to analysis of variance (Steel and Torrie, 1980). The Student-Newman-Keuls Multiple Range Test was used to evaluate differences between treatment means. The statistical analyses used was the General Linear Model (GLM) of SAS (1990) on Tuskegee University's DELVAX 11/780 minicomputer.

RESULTS AND DISCUSSIONS

The polypropylene mesh fabric blocked 71% of the incoming radiation from reaching plants under the tent (Table 1). This reduction was most pronounced during the afternoon hours. At 0900h there was a consistent reduction of 64% observed at 1300h. This high light penetration observed at 1300h was probably due to the angle of the sun relative to the position of mesh openings in the design of the fabric. It also appeared that light radiation was not uniformly distributed within the tent. The center of the tent received less radiation because access allowing vehicular traffic into the tent allowed higher levels of light to be observed in certain areas of the tent.

Table 1. Shade effect on light radiation transmision (watt m-^{2}) above canopy of hot pepper.

	0900 h		**1300 h**		**1700 h**	
	shade	full sunlight	shade	full sunlight	shade	full sunlight
East Position	40	114	69	180	9	78
Center Position	28	123	62	180	9	74
West Position	38	117	64	180	10	72
Average	34.3	118.0	64.3	180	9.3	74.0
%Reduction under shade	**70.1**		**63.7**		**87.6**	

Hot pepper plants exposed to continuous shade showed a marked increase in leaf area. Leaf area for plants grown under shade at 6 WAT was 4,396 cm^2 plant vs. 3737 cm^2 plant for plants grown in full sunlight (Fig. 1). However, as plants matured this difference was even more pronounced, with plants being exposed to continuous shade having 75% greater leaf area at 18 WAT (5,734 vs. 3,274 cm^2 plant). It is expected that leaf area would decline with age regardless of growing conditions. However, as hot pepper plants, leaf area declined under full sunlight but kept on increasing under shade, up to 18 WAT.

Plant height of plants grown both under shade and in full sunlight increased with time. However, plants under the polypropylene fabric were significantly taller at all stages of development than those grown in full sunlight (Fig. 2). At 6 WAT, plants grown in full sunlight were 42.3 cm in height and plants grown under shade were 74.0 cm tall. While continuously shaded plants were 75% taller initially, at the end of their production phase they were only 40% difference in height between the two sets of plants. The data obtained in this study on leaf area and plant height are in agreement with Jones (1995) who postulated that shading prolonged the juvenile stage of plant development.

Table 2. Shade effects on plant fruit production of hot pepper and results of AOV.

	Number of fresh fruit		Total fresh fruit weight		Unit fresh fruit weight	
	Mean + S.E.[1]	CV(%)	Mean + S.E.	CV(%)	Mean +S.E.	CV(%)
Full sunlight	32.9+4.1a	21.7	279.9+38.9a	24.1	8.5+0.3b	6.5
Shade	8.1+0.6b	10.4	90.2+ 6.3 b	9.9	11.1+0.04a	0.5
F-Test	21.4**(2)		14.1**		40.9***	

(1) Any two means with the same superscript are not significantly different using S-N-K P<0.05)
(2) *, **, *** Significant at 10%, 5%, and 1%

Hot pepper plants differed in how they produced vegetative biomass under shade versus full sunlight. Total fresh weight of hot pepper plants was reduced by 24% under shade and dry matter production by 18% (Fig. 3). Similar responses were noted with stem fresh and dry weights (24 vs. 29%), as well as leaf fresh and dry weights (24 vs. 5%) of shaded plants when compared with those grown under full sunlight (Fig. 3). However, stem to leaf ratios were not significantly influenced by shade. Total biomass and stem fraction kept increasing under both shade and in full sunlight. However, the leaf fraction kept on increasing in full sunlight but decreased under shade afetr 12 WAT. It should be further noted that the effect of shade on vegetative biomass production depended on the phase of plant growth. Total, stem, and leaf biomass production were high under shade at 12 WAT but less at 6 and 18 WAT. A similar trend was reported on peanut by Hang et al., (1984).

Light depletion under the polypropylene fabric reduced fresh fruit weight as well as number of fruits per plant by 210 and 306%, respectively (Table 2). This negative fruit yield response of "Scotch Bonnet" under shade was similar to that reported by Wolfe et al., (1989) for tomatoes but in this case, the yields were severely depressed (63%). It should be noted that individual fresh fruit weight of hot pepper increased under shade by 31%. Schou et al., (1978) working with soybeans and Hang (1984) working with peanuts had increased yields of individual components such as that observed with "Scotch Bonnet". Hang et al., (1984) indicated that average fruit weights of peanut was greater for shaded plants than the control, again suggesting low fruit numbers relative to assimilate supply. Large fruits are preferred by consumers of "Scotch Bonnet", therefore, growing the crop under shade holds some promise.

CONCLUSIONS

Light radiation under the polypropylene fabric was reduced by up to 87%. In general, continuous shade increased vegetative growth (leaf area and plant height) of "Scotch Bonnet" hot pepper plants. In contrast, shade reduced biomass accumulation and the number of fruits produced. Reduced yield was due primarily to fewer fruits per plant under shade. However, fruit size increased with shade. Economically, this is critical in marketing because large fruits are preferred when purchasing "Scotch Bonnet".

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Fig. 1. Effect of shade and harvest date on leaf area of hot pepper.

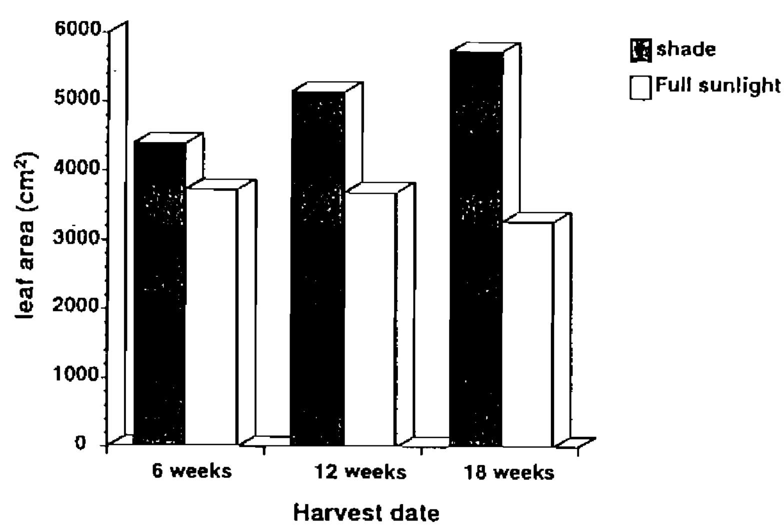

Fig. 2. Effects of shade and harvest date on height of hot peppers.

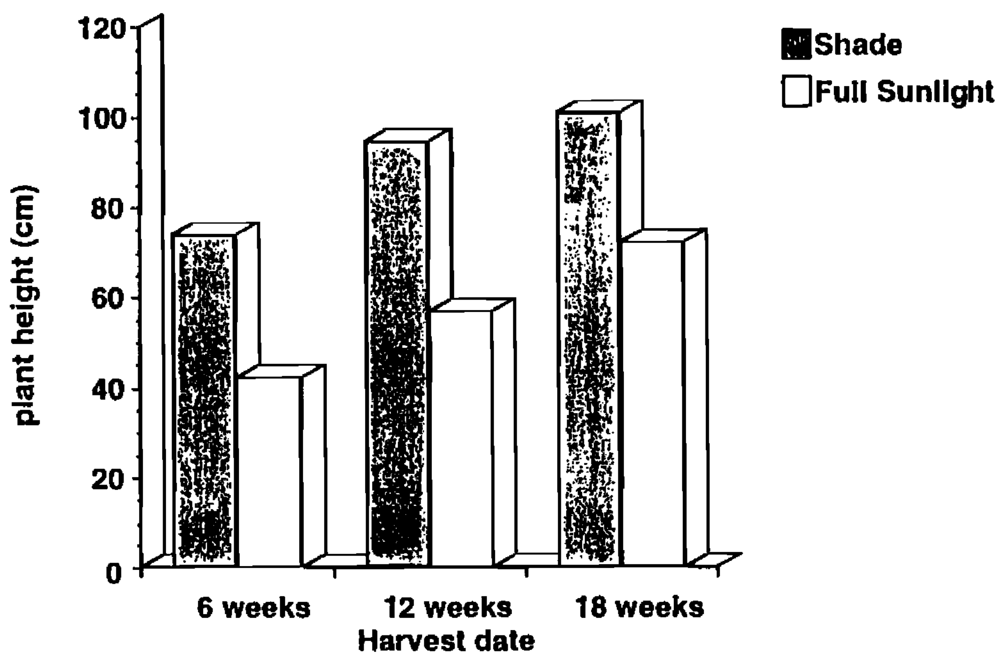

Fig. 3. Effects of shade and harvest on biomass production.