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Sunn hemp intercrop and mulch increases papaya growth and reduces wind speed and virus damage

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ABSTRACT

Papaya (*Carica papaya* L.) production in south Florida is limited by trade winds, storm wind damage, and papaya ringspot virus (PRSV) infection. This study was implemented to test a system intercropping sunn hemp (*Crotalaria juncea* L.) with papaya during papaya establishment, then mowing the intercrop and using it as a mulch on papaya beds. The study was performed in 2014 and repeated in 2015. Treatments included no sunn hemp (No-SH), sunn hemp mown early (SH-ME) 65 days after transplanting (DAT), and sunn hemp mown late (SH-ML) at 100 DAT. Wind speeds, sunn hemp growth and biomass contribution, papaya above ground growth, yield, flowering date, weeding time, and gas exchange variables, including net CO_2 assimilation (A) and stomatal conductance (g_s) of H_2O were measured. In 2015, additional measurements included PRSV infection rates and root growth via minirhizotron imaging. Results indicated a positive establishment environment as a result of the sunn hemp intercrop-mulching system. The system reduced weed pressure, reduced wind speed within papaya rows, and increased papaya growth after mowing and mulching. In 2015, standing sunn hemp reduced PRSV infection rates and hastened flowering. Mulching increased root growth in 2015, and A and g_s for 2 months after mulching. The SH-ML treatment led to elongation and reduced growth due to excessive shading. With the appropriate timing of mowing, this system promises improved production efficiency and reduced risks for south Florida papaya producers.

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1. Introduction

Papaya (*Carica papaya* L.) is a commercial crop in south Florida that currently provides low profits to growers due to a combination of low prices and low yields (Evans et al., 2012; Evans and Ballen, 2014). Because average papaya yields in south Florida are below those of other growing regions, increasing yields without increasing costs would be the most effective approach to improving papaya profitability in Florida (Evans et al., 2012). Challenges to papaya production in Florida include: papaya ringspot virus (PRSV), which limits the cropping cycle to approximately 2 yrs; water stress, caused by insufficient irrigation; and wind stress, due to trade winds (Evans et al., 2012). Additionally, tropical storms increase the risk of crop loss due to damage to young plants caused by high winds, often obligating growers to replant, losing time and capital (Migliaccio et al., 2010).

Intercropping a cover crop in the aisles of papaya rows for wind protection has been suggested as a low-cost alternative to constructed wind barriers (J. Crane, *personal communication*). Sunn hemp (*Crotalaria juncea* L.) may be a good candidate as an intercrop with papaya because it is a vigorous, leguminous species with an erect growth habit. In south Florida, sunn hemp has been found to add significant biomass (>9 Mg dry weight ha^{-1}) and nitrogen (>280 kg N ha^{-1}) to the soil (Abdul-Baki et al., 2001; Wang et al., 2005a,b, 2007). Despite these advantages, sunn hemp seed

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costs of greater than $0.011\,\mathrm{g}^{-1}$ had been prohibitive to growers. However, since 2013 sunn hemp seed costs have dropped to less than $0.0033\,\mathrm{g}^{-1}$ (Qingren Wang, personal communication), making it a viable option as a cover crop or intercrop. As a result, sunn hemp has become increasingly planted in south Florida as a cover crop for vegetable plantings (K. Bishop, personal communication). Additionally, planting sunn hemp as an intercrop reduced the incidence of viruses, including PRSV, in cucurbit crops (Manandhar and Hooks, 2011; Murphy et al., 2008). Further benefits of using sunn hemp as a cover crop preceding vegetable production include reduced nematode populations and increased soil microbial biomass, increased soil water holding capacity, and improved vegetable mineral nutrition (Sipes et al., 2002; Wang et al., 2005a,b, 2007). Thus, sunn hemp is an ideal species to test intercropping for wind protection of papaya. Although intercropping legumes can provide a series of advantages including increased available nitrogen to the cash crop (Govindarajan et al., 1996), there may be additional benefits to shade-adapted cash crops through intercropping with perennial species (Ramalho et al., 2000). However, we are not aware of any study that has addressed an intercropping system with short-term shading. For papaya, intercropping with sunn hemp is likely to provide benefits from wind protection without detrimental effects of shading because papaya displays environmental plasticity, acclimating effectively to light intensity as low as 2% of full sun (98% shade) and to rapid short-term fluctuations in irradiance (Allan et al., 1987; Buisson and Lee, 1993; Clemente and Marler, 1996). However, relatively moderate wind speeds ($4\,\mathrm{km\,h}^{-1}$) have been shown to significantly reduce photosynthesis and growth and exacerbate physiological impacts of water deficits on papaya (Clemente and Marler, 2001; Marler, 2011; Marler and Clemente, 2006). Therefore, wind protection afforded by an intercrop system may be a critical advantage to papaya production.

The objective of this study was to test the effects of utilizing a sunn hemp intercrop as a wind break and subsequent mulch on wind speed, shading, occurrence of weeds, and papaya growth, development, yield, water use, and virus infection. The study also examined the level of photoinhibition when shaded papaya leaves were suddenly exposed to full sun after mowing the sunn hemp intercrop. Measurements that are known to be responsive to shade or photoinhibition include specific leaf weight (SLW) and chlorophyll fluorescence. In shade acclimated papaya leaves, SLW is reduced relative to high-light acclimated leaves (Buisson and Lee, 1993). Photoinhibition caused by high light intensity can be readily detected by measuring variable to maximum chlorophyll fluorescence (Fv/Fm) as has been shown by Marler et al. (1994). The specific hypotheses tested were: 1) utilizing a sunn hemp cover crop in a papaya production system reduces wind speeds, the incidence of viral disease, and weed pressure, while shading the papaya; 2) increased shading from the sunn hemp will lead to shade acclimation in the papaya as estimated by specific leaf weight (SLW), causing photoinhibition as measured by Fv/Fm when the sunn hemp was mown; and 3) while growing, the sunn hemp intercrop would lead to increased water loss from the papaya bed due to increased transpiration, followed by decreased water loss from soil evaporation when the sunn hemp was mown and utilized as a mulch.

2. Materials and methods

2.1. Experimental design, establishment, and management

The study took place at the University of Florida Tropical Research and Education Center (Latitude: 25°30′40.809″N; Longitude: 80°30′3.983″W) with a Krome very gravely loam (loamy-skeletal, carbonatic hyperthermia lithic rendoll soil; Noble et al., 1996) and mean annual precipitation of 1505 mm (University of Florida, FAWN, 2016). This study was repeated twice, once in 2014 and once 2015. The experiment was arranged as a randomized complete block for each year, with 6 blocks. In 2014, blocks consisted of rows aligned north-south with a buffer row of papaya arranged between each block to allow airflow. After observing wind buffering effects in the middle of the planting during 2014, the planting was arranged in longer rows, with two blocks per row in 2015. This still provided a total of 6 spatially arranged blocks, but caused less buffering of wind speed in non-sunn hemp plots within the planting (reduced "edge" effects). Each plot received one of 3 treatments: 1) No sunn hemp (No-SH); 2) sunn hemp mown early (SH-ME), in which the sunn hemp was mown approximately 65 days after papaya transplanting (DAT); and 3) sunn hemp mown late (SH-ML), in which sunn hemp was mown approximately 100 DAT. In each sunn hemp treatment, the residue after mowing was placed uniformly on top of the papaya bed as a mulch. Plots were established by preparing 1.23-m beds on 3.69-m centers prior to planting sunn hemp. On 8 Apr 2014 and 23 Mar 2015 'Tropic Sunn' sunn hemp plants were planted in the aisles using a 2-m-wide seed drill. The drill was set to a 1.9-cm depth and calibrated to a rate of $56\,\mathrm{kg\,ha}^{-1}$ of seed within the planted area.

Papaya plant material was prepared by planting 'Red Lady' papaya seeds in trays in a greenhouse and watering as needed on a daily basis; seedlings were fertilized every 2 weeks through fertigation using a 20–20–20 ($N–P_2O_5–K_2O$) fertilizer (The Scotts Company, Marysville, OH). Approximately eight weeks after papaya seeds were germinated in flats, seedlings were transplanted to the prepared beds in the field on 4 June, 2014 and 19 May, 2015, approximately eight weeks after planting the sunn hemp in both years. Papaya seedlings were planted in groups of three plants per planting hole for the purpose of thinning to leave only one hermaphroditic plant per hole upon flowering, as is standard commercial practice. Plants were spaced 1.38 m apart within the row. Plants were sexed and thinned to the most vigorous hermaphroditic plant per hole as soon as all treatments had flowered to permit sexing, resulting in 10 plants per plot (1956 plants ha^{-1}). Immediately after planting, plants were fertigated using a solution of soluble 20–20–20 fertilizer at a rate of $6\,\mathrm{g\,L}^{-1}$ with an irrigation rate of $1.1\,\mathrm{L\,plant}^{-1}$ at each fertigation event (The Scotts Company, Marysville, OH, USA). Fertigation was repeated every 10 d for 40 d, after which plants were fertilized with granular fertilizer (6–6–6, Diamond R Fertilizer, Ft. Pierce, FL, USA) monthly at a rate of $270\,\mathrm{kg\,N\,ha}^{-1}\,\mathrm{yr}^{-1}$. A microsprinkler irrigation system with 1 emitter per plant at an emitter flow rate of $1.1\,\mathrm{L\,min}^{-1}$ was installed at planting. Irrigation was controlled via switching tensiometers connected to a timer system (Irrometer Company, Inc., Riverside, CA, USA). Tensiometers were placed in each plot and set to trigger irrigation up to twice per day if the soil water tension exceeded $-7\,\mathrm{kPa}$ at a rate of $1.1\,\mathrm{L\,min}^{-1}\,\mathrm{plant}^{-1}$ for a maximum of $10\,\mathrm{min\,day}^{-1}$ (approximately $2.2\,\mathrm{mm\,day}^{-1}$) in 5-min intervals.

Pest and disease management was performed by regularly scouting the crop and applying recommended pesticides as needed following the typical recommendations for papaya in the region (Crane, 2005). Weed management included a pre-plant application of glyphosate (GlyStar Plus, 49% ai., applied at $100\,\mathrm{L\,ha}^{-1}$ with 2.5% product mixture), followed by hand weeding during the study. In Mar 2015, PRSV was identified in the 2014 planting, followed by detection early in the 2015 planting. PRSV was managed by removal of symptomatic plants to slow transmission within the planting.

2.2. Measurements

Environmental and management measurements included wind speed, photosynthetically active radiation (PAR), total amount of