Biocompatibility of Sweetpotato and Peanut in a Hydroponic System

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Additional index words. *Ipomoea batatas*, *Arachis hypogaea*, allelopathy, intercropping, space agriculture, nutrient film technique

Abstract. ‘Georgia Red’ peanut (*Arachis hypogaea* L.) and TU-82-155 sweetpotato [*Ipomoea batatas* (L.) Lam] were grown in monocultured or intercropped recirculating hydroponic systems in a greenhouse using the nutrient film technique (NFT). The objective was to determine whether growth and subsequent yield would be affected by intercropping. Treatments were sweetpotato monoculture (SP), peanut monoculture (PN), and sweetpotato and peanut grown in separate NFT channels but sharing a common nutrient solution (SP-PN). Greenhouse conditions ranged from 24 to 33 °C, 60% to 90% relative humidity (RH), and photosynthetic photon flux (PPF) of 200 to 1700 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Sweetpotato cuttings (15 cm long) and 14-day-old seedlings of peanuts were planted into growth channels (0.15 $\times$ 0.15 $\times$ 1.2 m). Plants were spaced 25 cm apart within and 25 cm apart between growing channels. A modified half-Hoagland solution with a 1 N : 2.4 K ratio was used. Solution pH was maintained between 5.5 and 6.0 for treatments involving SP and 6.4 and 6.7 for PN. Electrical conductivity (EC) ranged between 1100 and 1200 $\mu\text{S}\cdot\text{cm}^{-1}$. The number of storage roots per sweetpotato plant was similar for both SP and SP-PN. Storage root fresh and dry mass were 29% and 36% greater, respectively, for plants in the SP-PN treatment than for plants in the SP treatment. The percent dry mass of the storage roots, dry mass of fibrous and pencil roots, and the length-to-diameter ratio of storage roots were similar for SP and SP-PN sweetpotato plants. Likewise, foliage fresh and dry mass and harvest index were not significantly influenced by treatment. Total dry mass was 37% greater for PN than for SP-PN peanut plants, and pod dry mass was 82% higher. Mature and total seed dry mass and fibrous root dry mass were significantly greater for PN than for SP-PN plants. Harvest index (HI) was similar for both treatments. Root length tended to be lower for seedlings grown in the nutrient solution from the SP-PN treatment.

The concept of use of biological systems for life support in space has been studied since the early 1950s, with emphasis on the use of algae (e.g., chlorella) to help regenerate O_2 through photosynthesis (Golueke and Oswald, 1964; Krall and Kok, 1960). Research was expanded in the late 1960s and early 1970s to include higher plants. In the mid-1970s, the National Aeronautics and Space Administration (NASA) created the Controlled Ecological Life Support System (CELSS) program to conduct research on bioregenerative life support using candidate plant species (MacElroy and Bredt, 1985), including sweetpotato and peanut, as potential food sources for humans

on extended space missions. Both crops are being grown hydroponically with the nutrient film technique at Tuskegee Univ.’s NASA Center for Food and Environmental Systems for Human Exploration of Space (CFESH) to evaluate their cultural, nutritional, and physiological responses in controlled environments.

Growing several plant species in a CELSS will afford greater stability than growing only a few (Cooke, 1971). In a multispecies system, plants will not only be grown in close proximity to each other, but will also share a common nutrient solution. Therefore, determining if these crops are biocompatible is critical; if not, they must be grown in isolation. Plant allelopathic compounds have been reported for species selected for CELSS (Peterson and Harrison, 1992; Rice, 1984). Sweetpotato produces allelopathic compounds and has been used as a natural weed suppressant in polycropping systems (Peterson and Harrison, 1992). Tibbitts et al. (1994) grew ‘Norland’ potato and ‘Yeco Rojo’ wheat for 35 d in a biocompatibility study and reported lower dry mass for both crops when they shared a common nutrient solution rather than having separate nutrient sources. They concluded that there were no significant allelopathic effects of potatoes on wheat but that the low dry masses obtained warranted further study. Schuerger and Laible (1994) grew ‘Yeco Rojo’ wheat and ‘Florida

Petite’ tomato in a recirculating hydroponic system and found no significant adverse effects on the growth of either crop.

The objectives of this study were to determine whether growth and subsequent yield would be adversely affected when sweetpotato and peanut shared a common nutrient solution, and to test whether allelopathic compounds accumulated in the nutrient solution in which the plants were grown.

Materials and Methods

Vine cuttings (15 cm) of the sweetpotato breeding clone TU-82-155 and 2-week-old ‘Georgia Red’ peanut seedlings were grown in double Tuskegee Univ. nutrient film technique (NFT) channels (0.15 $\times$ 0.15 $\times$ 1.2 m each section) in a greenhouse during 1996 and 1997. Treatments were sweetpotato (SP) and peanut (PN) as monocultures, and both crops grown separately but sharing the same nutrient solution (SP-PN), arranged in a completely randomized design with three replications per treatment.

A modified half-Hoagland nutrient solution (Hoagland and Arnon, 1950) with a 1 N : 2.4 K ratio was used. Each channel was inclined with a 1% slope and was supplied by a 30-L reservoir. The solution pH was maintained between 5.5 and 6.0 for treatments involving sweetpotato, and 6.4 to 6.7 for PN, by manual addition of either dilute NaOH or HCl. Electrical conductivity was maintained between 1000 and 1200 $\mu\text{S}\cdot\text{cm}^{-1}$ and solutions were replenished twice per week with a modified half-Hoagland stock. The solution was continuously pumped from each reservoir to the high end of each growth channel by small magnetic drive pumps (Little Giant model 2P037; Tecumseh Products Co., Oklahoma City, Okla.) The nutrient solution spread across the bottom of each growing channel in a thin film and emptied into a reservoir. The flow rate was set at 1 L $\cdot\text{min}^{-1}$ by using a bypass return line back to the reservoir with a control valve. Each vine cutting was held in place by a flat-plate assembly (Morris et al., 1989) attached to the side of the channels by a flexible black/white vinyl covering. Plants were trained by tying them to vertical strings dropping $\approx$ 1 m from above each growing channel. Greenhouse temperatures ranged from 24 to 33 °C. Photosynthetic photon flux varied with weather conditions and ranged from 200 to 1700 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Relative humidity ranged between 60% and 90%.

Plants of both crops were harvested 120 d after planting. Sweetpotato roots with diameters >1 cm were harvested as storage roots, and roots with <1 cm in diameter, but with distinct pigmentation, were harvested as pencil roots. All remaining roots were classified as fibrous roots. After each storage root was removed and weighed, the middle 5-cm section was removed, cut into smaller pieces, and chopped in a food processor. After thorough mixing, a 25-g sample was taken and dried at 70 °C for 72 h, to determine dry mass. This information was used to calculate a fresh-to-dry-mass conversion factor to estimate stor-

Received for publication. 23 Dec. 1997. Accepted for publication 15 May 1998. Contribution no. 302 of the George Washington Carver Agricultural Experiment Station, Tuskegee Univ.. This research was supported by funds from the U.S. National Aeronautics and Space Administration (Grant No. NAGW-2940) and USDA/CSREES (Grant No. ALX-SP-1). The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 1. Effects of intercropping with peanut on mass of storage and fibrous root and foliage mass and on harvest index (HI) of sweetpotato grown in nutrient film technique.

Treatment ^a	Storage root				Pencil roots		Fibrous root		Foliage mass		HI (%)
	No. per m ²	Fresh mass (g·m ⁻²)	Dry mass (g·m ⁻²)	Dry mass (%)	dry mass (g·m ⁻²)	L/D ^b ratio	dry mass (g·m ⁻²)		Fresh (g·m ⁻²)	Dry (g·m ⁻²)	
SP	19.3	4306	686	15.8	29.0	2.3	43.5		3500	351	63.2
SP-PN	23.4	5532	935	16.4	31.4	2.6	62.9		4048	444	59.9
P	NS	0.01	0.05	NS	NS	NS	NS		NS	NS	NS

^aLength-to-diameter ratio.^bPN—monoculture; SP-PN—sweetpotato.

age root dry mass. The remainder of the plant tissue was dried for 72 h at 70 °C and weighed. After determining the fresh weight of the peanut pods and remaining plant tissue, they were dried at 35 and 70 °C, respectively, for 72 h. After drying, pods were shelled and seeds were classified as mature (seeds with a smooth testa, pink to dark pink with a more rounded appearance) or immature (seeds having testa with longitudinal wrinkles, light color, and slightly elongated) according to the method of Rucker et al. (1994).

A modified allelopathic bioassay of the nutrient solutions was conducted according to the method of Schueger and Mitchell (1992), to determine whether plant allelopathic compounds accumulated in the nutrient solutions. 'Waldmans Green' lettuce (*Lactuca sativa* L.) seeds were germinated in commercial Jiffy Mix (Batavia, Ill.) in a growth chamber set at 28 °C day/22 °C night. Before seedlings were transferred to the nutrient solutions, they were carefully removed from the germinating media to minimize root damage, and rinsed of excess media. Four seedlings were placed into openings in a styrofoam disk. This disk was transferred into 4-L pots containing the respective nutrient solutions in a completely randomized design with three nutrient solution treatments and four replications. The 12 pots were placed in a reach-in growth chamber having a 12-h photoperiod, 70% RH, and a 28/22 °C diurnal temperature. Plants were harvested after 14 d and root length measurements were taken.

The experiments were repeated and the data were combined by treatments and subjected to an analysis of variance. Mean separation was determined using the *t* test (Steele and Torrie, 1980; SAS, 1985).

Results and Discussion

The number of storage roots per sweetpotato plant was similar for both SP and SP-PN (Table 1). However, storage root fresh and dry mass were ≈29% ($P < 0.01$) and 36% ($P < 0.05$) greater, respectively, for plants in the SP-PN treatment than for those in the SP treatment. The percent dry mass of the storage roots, dry mass of fibrous and pencil roots, and the length-to-diameter ratio of storage roots were similar for SP and SP-PN plants. Likewise, foliage fresh and dry mass, and harvest index were not significantly influenced by either treatment.

Total plant dry mass (Table 2) was ≈37% greater, and total pod dry mass 82% greater, for monocultured (PN) peanut plants than for

Table 2. Effects of intercropping with sweetpotato on total plant, pod, and fibrous root dry mass, seed yield, and harvest index (HI) of peanut grown in nutrient film technique.

Treatment ^a	Total plant dry mass (g·m ⁻²)	Pod dry ^a mass (g·m ⁻²)	Fibrous root dry mass (g·m ⁻²)	Seed yield		HI (%)
				Total (g·m ⁻²)	Mature (g·m ⁻²)	
PN	947	485	147.4	384	372	27.4
SP-PN	696	266	97.4	191	182	23.2
P	0.10	0.05	0.0001	0.02	0.02	NS

^aPod yield includes both shell and seed mass/^bPN—monoculture; SP-PN—sweetpotato.

those sharing a common nutrient solution with sweetpotato (SP-PN). Mature and total seed dry mass, and fibrous root dry mass were also significantly higher in monocultured (PN) plants (Table 2). Harvest index (HI) was similar between PN and SP-PN treated plants, suggesting that the distribution of dry matter between vegetative and reproductive parts of the peanut plants was not altered by the SP-PN treatment. A high harvest index is particularly important in an advanced life support system since less noninedible biomass would accumulate, reducing the need for waste disposal.

Root lengths (18.4 and 15.4 cm for PN and SP, respectively) of lettuce seedlings in bioassays were similar for seedlings grown in nutrient solutions from PN and SP treatments, but tended ($P < 0.06$) to be lower (12.2 cm) for seedlings grown in nutrient solution from the SP-PN treatment.

These results show that intercropping with peanut had no significant adverse effects on sweetpotato growth and yield. In fact, the greater storage root fresh and dry mass for plants grown in the SP-PN treatment suggests that the roots of the peanut plants may have exuded beneficial plant growth-promoting compounds into the nutrient solution (N-fixation was ruled out as a possible explanation since the system was free of N-fixing bacteria and no nodules were formed on the roots). In contrast, however, peanut growth and yield were adversely affected when both crops shared a common nutrient solution. For example, while foliage dry mass tended to be similar for PN and SP-PN plants, pod and seed yields were substantially reduced in the latter plants. The adverse effects of sweetpotato on peanut growth suggest that plant growth-inhibiting substances from the sweetpotato may have accumulated in the nutrient solution. Reproductive growth appeared to be affected much more than vegetative growth (including pod initiation, development and filling, and seed maturation). The inhibitory effect of sweetpotato on peanut growth agrees with the findings of others using different species. Harrison and

Peterson (1986) reported lower dry-mass accumulation in yellow nutsedge (*Cyperus esculentus* L.) and alfalfa (*Medicago sativa* L.) plants grown in soil from a sweetpotato field or in a potting medium containing decomposing sweetpotato plants. Similarly, Walker and Jenkins (1986) reported that dry mass of cowpea [*Vigna unguiculata* (L.) Walp.] was reduced an average of 75% when grown in media containing either sweetpotato vines or storage root residues. Depending on cultivar, the sweetpotato storage root periderm has a high concentration of phenolic compounds that are continually sloughed off and replaced during growth (Harrison and Peterson, 1986). This phenomenon could partly explain the source of the plant-growth inhibitory substances in the nutrient solution.

There was some evidence from the lettuce bioassay (as measured by root length) to support the notion that allelopathic compounds accumulated in the SP-PN nutrient solutions. Roots of lettuce seedlings grown in the SP-PN solution were ≈34% shorter than those of plants grown in the PN solution. This response is contrary to the findings of Schueger and Laible (1994), who found no evidence of accumulation of allelopathic compounds when wheat and tomato were intercropped. However, although lettuce is sensitive to different stresses and is widely used as a test species, certain other test species may have yielded a more consistent response.

These data document a serious problem in intercropping sweetpotato with peanut growth. Although they can be grown together, peanut seed yields may be reduced by inhibitory substances exuded by sweetpotato roots.

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