Cowpeas and pinto beans: yields and light efficiency of candidate space crops in the Laboratory Biosphere closed ecological system

M. Nelson1,2, W.F. Dempster1,2, S. Silverstone1,2, A. Alling1,3, J.P. Allen1,2,3 and M. van Thillo1,3

(1) Institute of Ecotechnics, 24 Old Gloucester St., London WC1 3AL, U.K.

(2) Biospheric Design Division, Global Ecotechnics Corp., 1 Bluebird Court, Santa Fe, NM 87508 USA

(3) Biosphere Foundation, 9 Silver Hills Rd, Santa Fe, NM 87508 USA

nelson@biospheres.com

Abstract

An experiment utilizing cowpeas (*Vigna unguiculata*), pinto beans (*Phaseolus vulgaris* L.) and Apogee ultra-dwarf wheat was conducted in the soil-based closed ecological facility, Laboratory Biosphere, from February to May 2005. The lighting regime was 13 hours light / 11 hours dark at a light intensity of 960 μmol $m^{-2}s^{-1}$, 45 moles m^{-2} day^{-1} supplied by high-pressure sodium lamps. The pinto beans and cowpeas were grown at two different plant densities. The pinto bean produced 710 g m^{-2} total aboveground biomass and 341 g m^{-2} at 33.5 plants per m^2, and at 37.5 plants per m^2, produced 1092 g m^{-2} total biomass and 537 g m^{-2} of dry seed, an increase of almost 50%. Cowpeas at 28 plants m^{-2}, yielded 1060 g m^{-2} of total biomass and 387 g seed m^{-2}, outproducing the less dense planting by more than double (209%) in biomass and 86% more seed as the planting of 21 plants m^{-2} produced 508 g m-2 of total biomass and 209 g m-2 of seed. Edible yield rate (EYR) for the denser cowpea bean was 4.6 g m^{-2} day^{-1} vs 2.5 g m^{-2} day^{-1} for the less dense stand; average yield was 3.5 g m^{-2} day^{-1}. EYR for the denser pinto bean was 8.5 g m^{-2} day^{-1} vs 5.3 g m^{-2} day^{-1}; average EYR for the pinto beans was 7.0 g m^{-2} day^{-1}. Yield efficiency rate (YER) the ratio of edible to non-edible biomass was 0.97 for the dense pinto bean, 0.92 for the less dense pinto bean, and average 0.94 for the entire crop. The cowpeas were both lower in YER, and for that crop the less dense stand had a higher YER: 0.70 vs 0.58 for the dense crop, and overall cowpeas had a YER of 0.64. For the denser and less dense pinto bean, average light efficiency was 0.41 – 0.26 grams total biomass per mole, and 0.20 – 0.13 grams seed per mole, respectively. For the cowpeas, light efficiency for total dry biomass was 0.29-0.14 grams per mole, and 0.11 – 0.06 g seed per mole of light for denser/less denser cowpea crops. Electrical energy efficiency (grams of edible biomass per kWh of energy used for lighting) was 3.6 g $kWh^{-1}$for the dense

pinto bean stand, 2.3 g kWh^{-1} for the less dense stand, and averaged 3.0 g $kWh^{-1}$for the pinto beans; while the dense cowpea was 1.95 g kWh^{-1} ,the less dense cowpeas had an efficiency of 1.05 g kWh^{-1} and the entire cowpea crop was 1.50 g kWh^{-1}. The crop was grown at elevated atmospheric carbon dioxide levels, with ambient levels ranging from 500-3000 ppm daily during the majority of the crop cycle. During early stages (first 20 days) of the crop, CO2 was allowed to rise to 7500 ppm because while soil respiration dominated, then was brought down by plant photosynthesis and after day 30, daily injections of CO2 were made. Compared to projected pinto bean yields for the prospective Mars life support facility, the “Mars on Earth” space base life support system, the denser stand of pinto beans yielded over twice (230%) more, the average yield was 89% higher, and the less dense stand was 46% higher than those projected yields. Cowpea yields for the best, densest cropping was 25% higher than life support projections of 3.7 g m^{-2} day^{-1} for the dry bean component of that space agriculture diet.