Perennial Sunflower Provides Food and Ecosystem Services

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Abstract

Global population is projected to reach nine billion people by 2050, and the human population will need an adequate food supply and methods for sustainable production (Baulcombe et al., 2009). Over the past century, agricultural science has greatly increased crop yields and productivity. However, this increase in productivity has often come at the expense of long term environmental sustainability through overuse of fossil fuel-based fertilizers, and the depletion of fresh water and arable land (Tilman et al., 2002). Addressing environmental damage is essential for the production of adequate food. Future cropping systems will need an increased emphasis on ecosystem services (Costanza et al., 1997). Ecosystem services can be incorporated into the landscape by increasing nutrient and water efficiency in major crops, adjusting agronomic practices (timing and duration of irrigation and nutrient applications), and by using perennial crops to help maintain healthy nutrient levels, control erosion and pests, and to keep water clean (DeHann et al., 2005; Baulcombe et al., 2009; Jackson and Berry, 2009; Glover et al., 2010). The objective of this research is to use current genetics and plant breeding techniques to introgress genes for perennial habit from *Helianthus tuberosus* L. (2n=6x=102) into domesticated sunflower (*Helianthus annuus* L., 2n=2x=34). *H. tuberosus* is part of the secondary gene pool of sunflower and has been used as a donor of many disease resistance traits making it an excellent donor for perennial habit. Because of previous success in gene transfer from *H. tuberosus*, we believe we will be successful in transferring perennial habit into annual sunflower.

Background

Perennial plants naturally allocate more resources into perennial organs (asexual) rather than seed (sexual). However, this difference in allocation can be overcome because perennial plants have more time to assimilate resources than annual plants and may divert resources to both sexual and asexual reproduction (Cox et al., 2002; DeHaan et al., 2005), so there is no reason why a perennial plant cannot be selected for increased seed yield. In addition to reducing the environmental impact of agricultural systems through reduction in fall tillage, soil erosion and nutrient runoff, the reduced input costs for perennial crops can lead to profitability equal to annual counterparts if the yield of the perennial crop is 60-100% (depending on soil type and assuming an equal price) of the annual over their life of the stand (Bell et al., 2008). Recent work has shown that the genetics of perenniality (developing of perennial organs) may not be as complex as previously believed, with only few (1 or 2) quantitative trait loci (QTL) needed (Wang et al., 2009; Sacks et al., 2003; Hu et al., 2003; Hulke and Wyse, 2008).

Objectives

1) Assess the relationship of perennial, agronomic, and fertility phenotypes in interspecific sunflower populations.

2) Advance the current interspecifc sunflower populations.

Design

Fifteen traits were scored on 187 F1 hybrids (*H.tuberosus x H. annuus*) and 18 *H. tuberosus* parents in 2009 and 2010 in St. Paul, Minnesota and in 2010 in Rosemount, Minnesota. The plants were planted in a randomized complete block design with three replications. Intermated F1 (IM1F1were evaluated for ability to overwinter in St. Paul in 2009 and for flower and seed characteristics in St. Paul in 2010 in unreplicated space plantings.

Populations

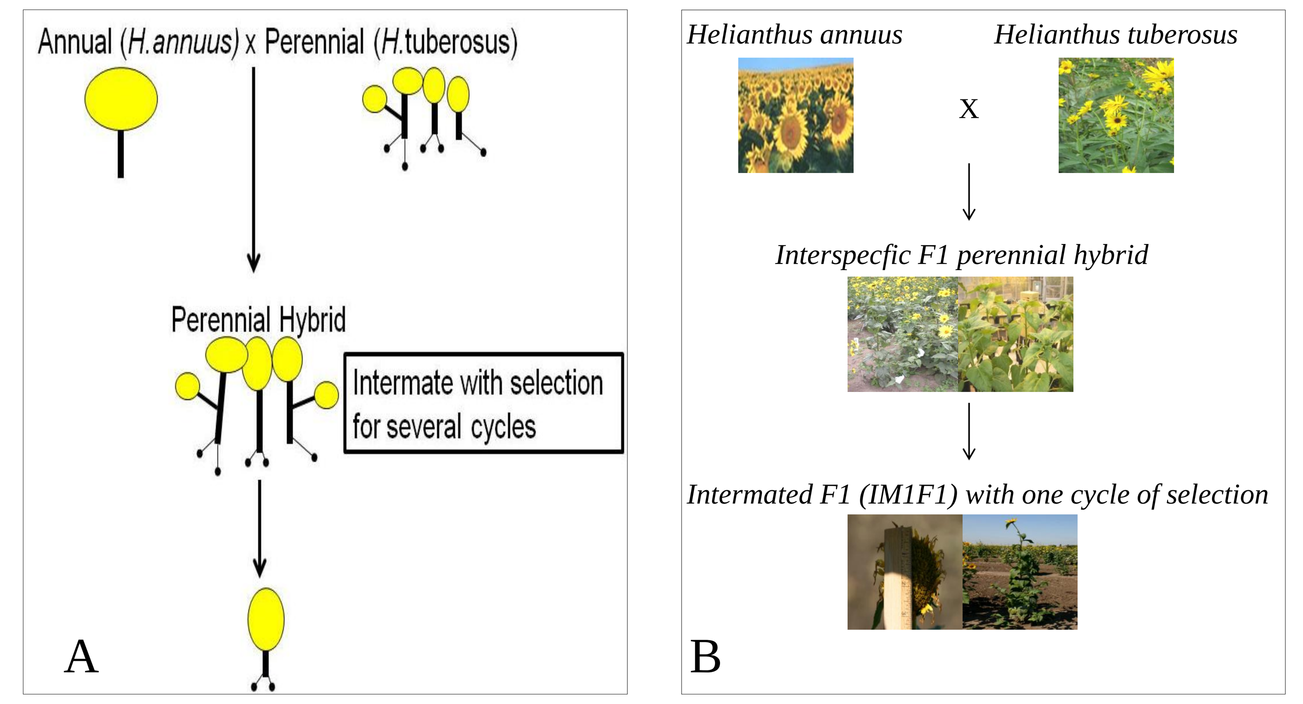
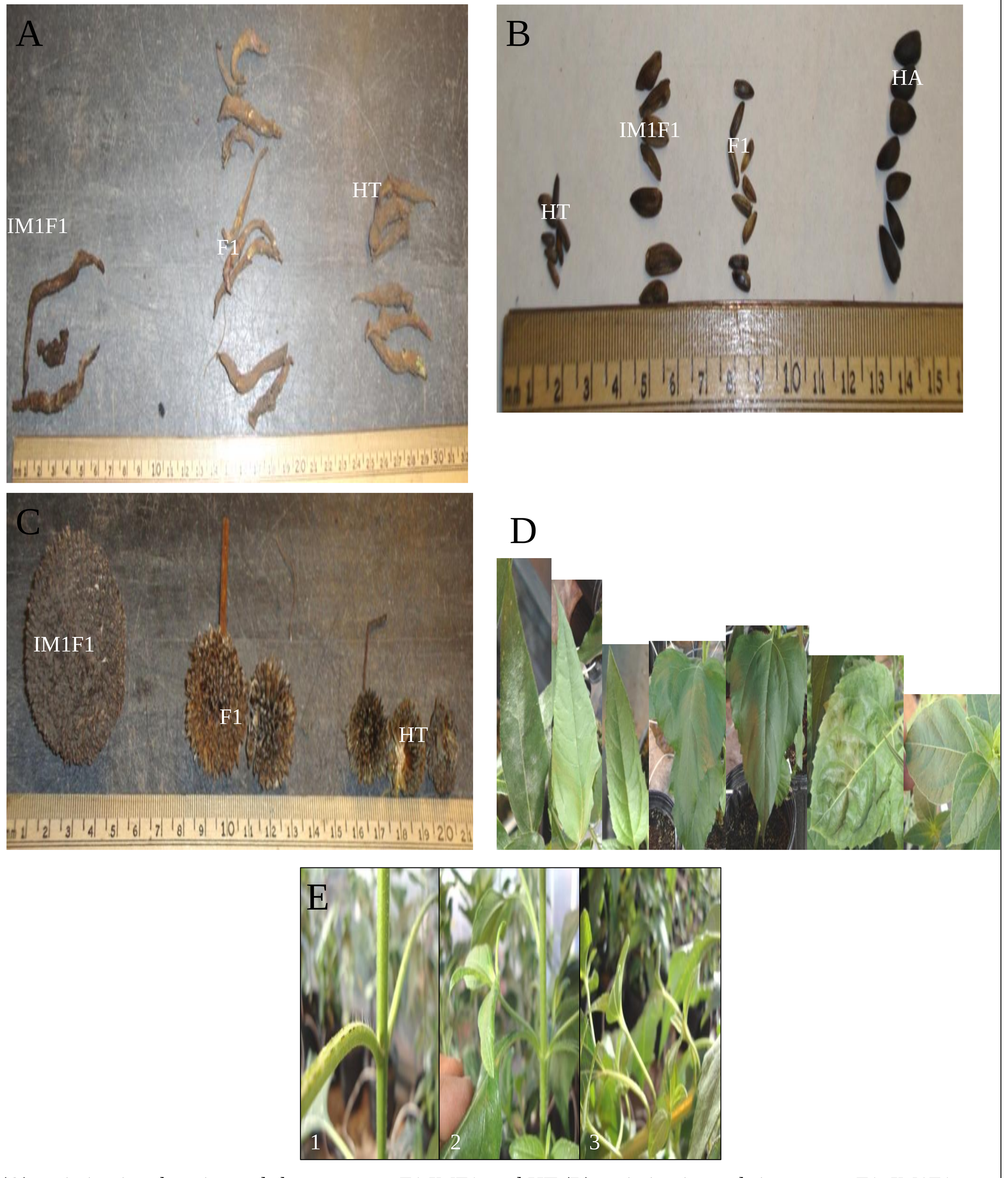


*Figure 1 shows (A) method for perennial grain development (B) the current populations

Results

•Figure 2 shows the large amount of variation present in the F1 with traits showing intermediate phenotypes to the wild and domestic parents, but with selection more domestic like phenotypes are recovered



*(A) variation in tuber size and shape among F1,IMF1, and HT (B) variation in seed size amongF1, IM1F1, HT, and HA (C) variation in flower size in F1, IMF1, and HT (D) variation in leaf shape, lanceolate to ovate (E) variation in branching (1) no branching (2) minimal branching (3) Profuse branching. HT=*Helianthus tuberosus*, HA=*Helianthus annuus*, F1= Cross between HT and HA, IM1F1= First intermated generation of F1

Conclusions

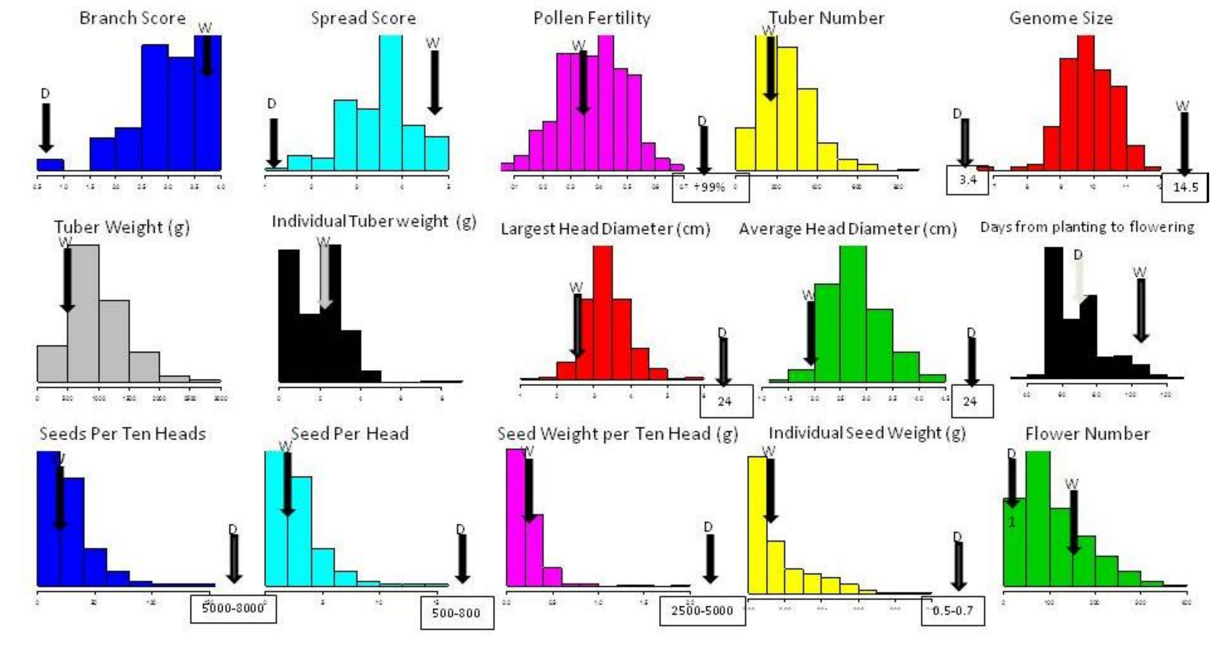
•The long term goal is to develop an *H. annuus*-like plant that produces tubers and yield grain consistently over the life of a stand, leading to a crop that produces ecosystem services while having a commercially viable yield.

•The ideal perennial sunflower would have good seed characteristics (pollen fertility, seed weight, flower size), good agronomic characteristics (low branch numbers, low flower numbers), and weak perennial characteristics (low tuber number, high individual tuber weight).

•Progress
- •After one intermating generation we see large improvement toward a domestication phenotype
- •Recurrent selection with a focus on flower characteristics and yield will provide a way to develop a perennial grain.
- •This crop has many potential uses on different landscapes
  - •A trap crop for black birds
  - •A commercial option on degraded landscapes

Results Continued

•Figure 3 shows the variation present in the F1 with traits showing intermediate phenotypes to the wild and domestic parents



†Annual sunflower phenotypes (boxes under arrows) are from: D.H. Putnam, E.S. Oplinger, D.R. Hicks, B.R. Durgan, D.M. Noetzel, R.A. Meronuck, J.D. Doll, and E.E. Schulte. 1990. Sunflower. Alternative Field Crops Manual. Univ. of Minnesota and Univ. of Wisconsin. St. Paul, MN.

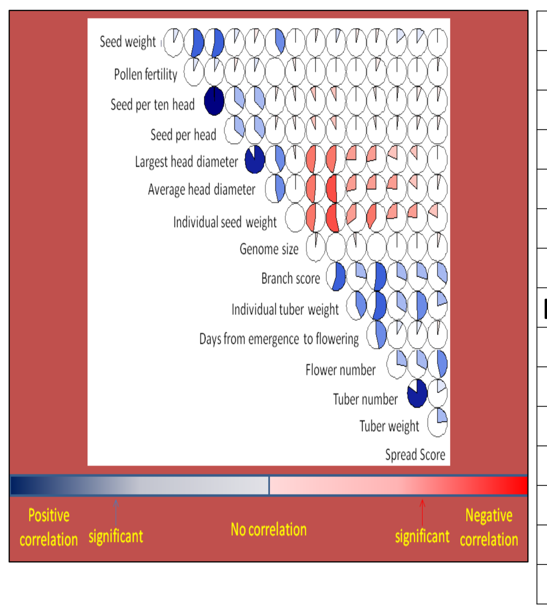
*Trait distributions for all phenotypes examined. D indicates where domestic annual sunflower is on the distribution; W indicates where the wild perennial sunflower would fall on the distribution. Boxes under arrows indicate the phenotype if it is beyond the distribution.

•Figure 4 shows that tuber characteristics are negatively correlated with flower size but not seed characteristics

•Pollen fertility is correlated with any other trait

•Tuber traits are highly heritable

•Flower traits are moderately heritable



Trait	Heritability
Tuber number	0.66
Tuber weight (g)	0.61
Average head diamater	0.60
Individual tuber weight (g)	0.48
Largest head diamater	0.48
Seed per ten head	0.39
Days from germinaiton to flowering	0.33
Branch Score	0.32
Seed per head	0.31
Individual seed weight (g)	0.22
Flower number	0.18
Seed weight (g)	0.16
Spread score	0.12
Pollen fertility	0.05

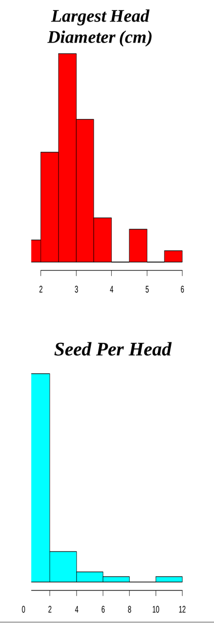
* Trait correlations for all phenotypes examined averaged over locations. Circles indicate the magnitude of the correlation.

•Sixty intermated F1(IM1F1) plants were scored for flower and seed characteristics

•Figure 5 the improvement characteristics (larger head size and more seed per head) was larger than the F1

•The largest head was 20% larger than any head present in the F1

•The IM1F1 plants also were segregating for perenniality with greenhouse and field growth showing that only ¾ of the IM1F1were perennial



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