International Perennial Wheat Genotype x Environment Trial; Observations from Minnesota

MK Turner [1], Richard Hayes [2], and JA Anderson [1]

[1] Department of Agronomy and Plant Genetics, University of Minnesota, St Paul, MN; [2] New South Wales Department of Primary Industries, Wagga Wagga, Australia

Introduction

Compared with annual crop species, perennials provide continual cover (Fig. 1), retain higher soil fertility (Culman et al., 2010), prevent loss of N and P through surface runoff (Turner and Rabalais, 2003), protect against soil erosion, and are more resilient to pathogens and abiotic stresses (Glover, 2005). Despite many potential benefits, perennial wheat (Fig. 2) survival is variable in different environments. In 2009, 52 genotypes were planted in Minnesota, but only 2 survived to produce seed for two years and seed production was very low in the second year (Turner et al. 2013). To test the survival of the current germplasm we are collaborating on a study coordinated by the New South Wales Department of Primary Industries, Wagga Wagga, Australia.

Objectives

I. Determine whether lines that have survived ≥ 2 years at Cowra, Australia, can also survive in contrasting environments.
   a) Does genotype affect survival?
   b) How do experimental perennial wheat entries compare to perennial checks and annual wheat?
   c) Is performance consistent over years?

II. Determine what (if any) environmental factors are inhibiting plant survival.

Planting in St. Paul 2012

- Thirteen perennial wheat (*Triticum spp.*x *Thinopyrum spp.* derivatives) were grown at more than 15 sites across 8 countries.
- Sites included one location planted in St. Paul, MN in September 2012 in 1 m rows with 0.5 m spacing and three replications (Fig. 3).
- Checks included *T. aestivum* (winter wheat 'Arapahoe' and Australian winter wheat 'Wedgetail'), *Th. intermedium* (C3-2627 and Minnesota intermediate wheatgrass), and *Secale montanum* (mountain ryegrass Family 10) (Fig. 4).

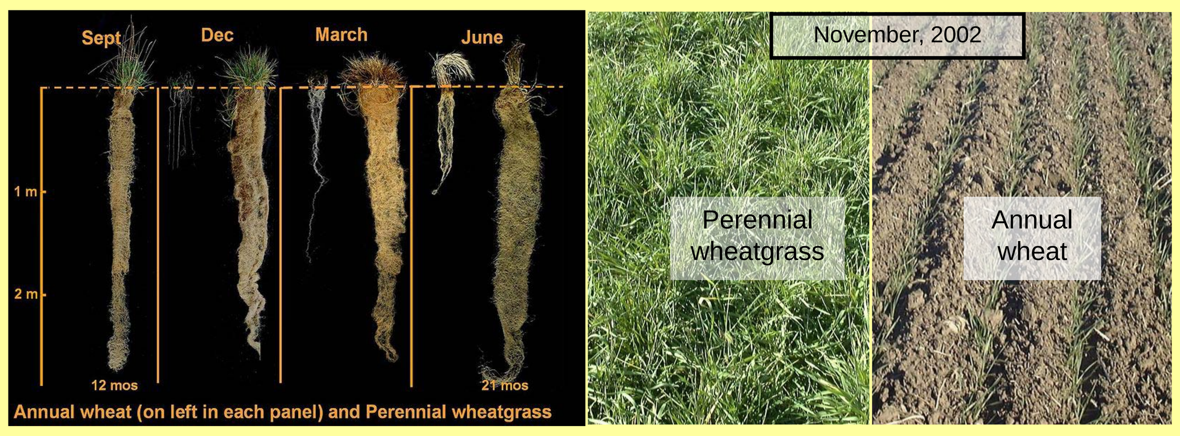

Figure 1. Perennial wheatgrass and annual wheat above and belowground structures at time points throughout the year. (Photos from Jerry Glover and Lee DeHaan)

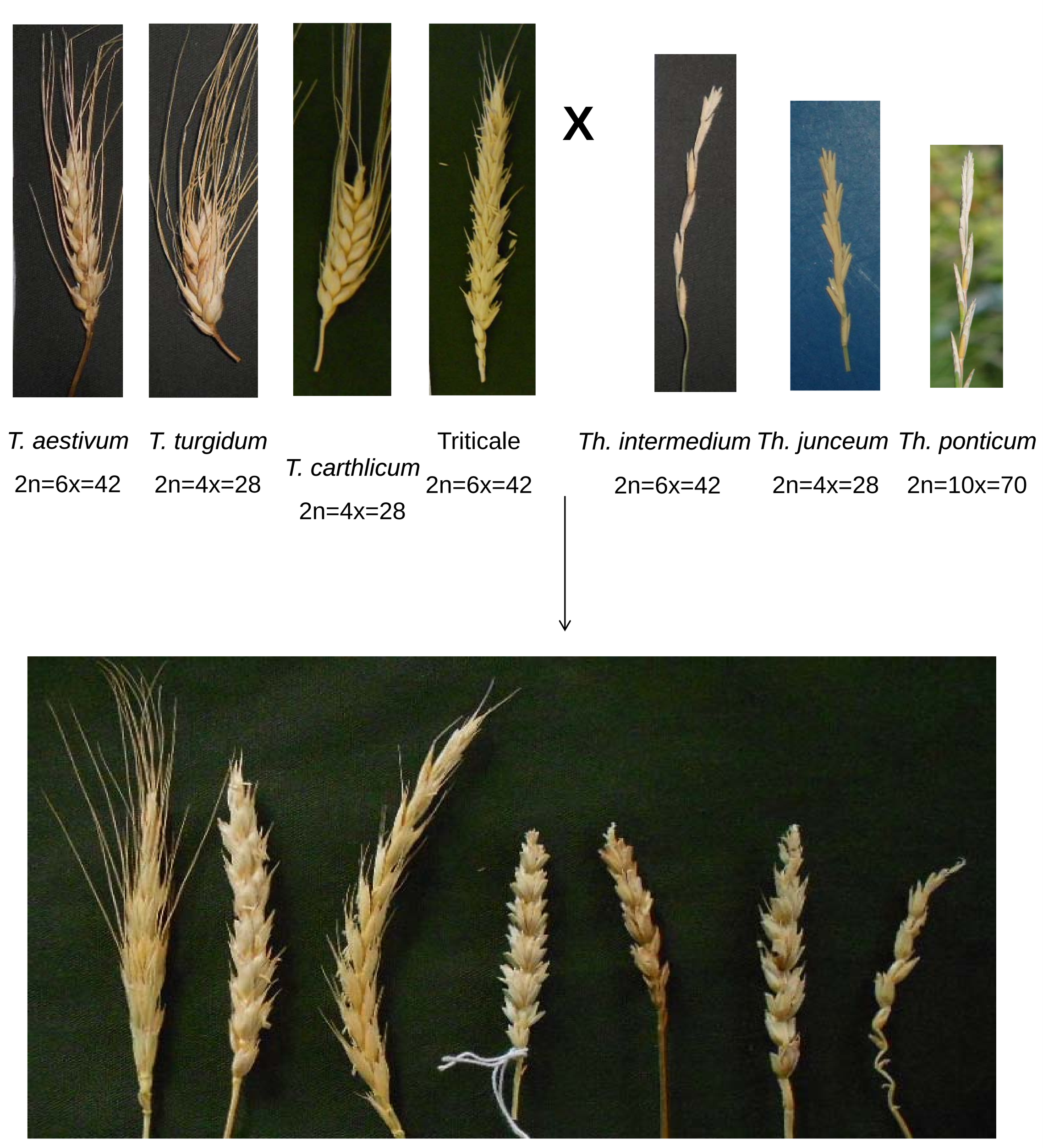

Figure 2. a) Annual wheat and perennial wheatgrass species used to derive perennial wheat lines b) perennial wheat heads resulting from crosses between species above.

Figure 3. Perennial wheat trial planted in St. Paul, MN in September 2012. Plants surviving post first harvest. Photo taken in the fall of 2013.

Regrowth in 2013 and 2014

- Eight of 13 perennial wheat entries survived the first winter (2012/2013) and produced seed (Fig. 5), however only four entries survived across all three replications. In contrast, all perennial grass controls survived the first winter and produced seed.
- Following seed production, seven of eight perennial wheat entries regrew in the fall of 2013. In the second growing season, six of the seven regrowing lines survived the winter (2013/2014).
- Survival was related to the pedigree and wheatgrass species. The majority of the surviving lines (four/six) shared the pedigree *Thinopyron elongatum* (2n=14, EE)/Chinese Spring//Madsen and the other two surviving lines are derived from crosses to *Th. intermedium*. Not all perennial wheat lines derived from *Th. intermedium* survived.

a

Genotype	Species derivation
C3-2627	Thinopyrum intermedium
MN-iwg	Intermediate wheatgrass
Family 10	Secale montanum
Arapahoe	Triticum aestivum
Wedgetail	Triticum aestivum
OK 72	T. aestivum x Th. ponticum
12F3256	T. aestivum x Th. Ponticum
12F3258	T. aestivum x Th. Ponticum
12F3205	T. aestivum x Th. Intermedium
12F4090	T. aestivum x Th. intermedium
280b	T. aestivum x Th. intermedium
B374-6-7s	T. aestivum x Th. intermedium
Ot 38	T. aestivum x Th. intermedium
235a	T. aestivum x L. elongatum
236a	T. aestivum x L. elongatum
244b	T. aestivum x L. elongatum
251b	T. aestivum x L. elongatum
11955	T. aestivum x Agropyron spp.

b

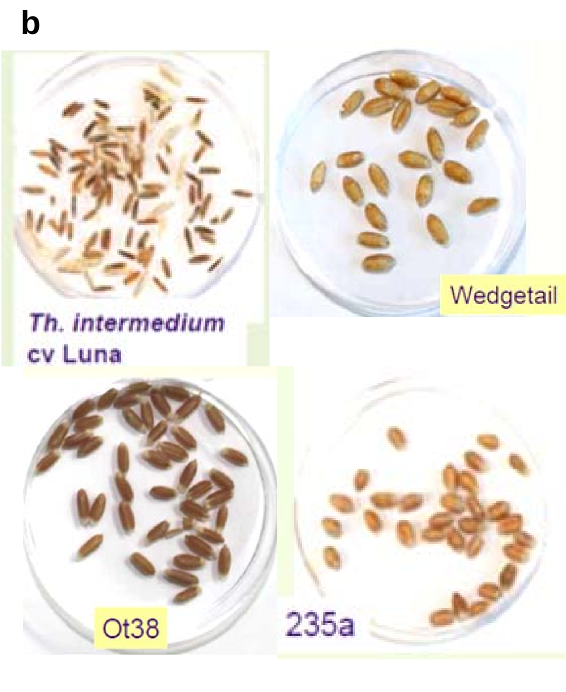

Figure 4. a) Genotypes for perennial wheat GxE trial, color coded by species. b) Selected perennial wheat seed compared with *T. aestivum* cv. Wedgetail and *Th. intermedium* cv. Luna. (Photos from Phil Larkin)

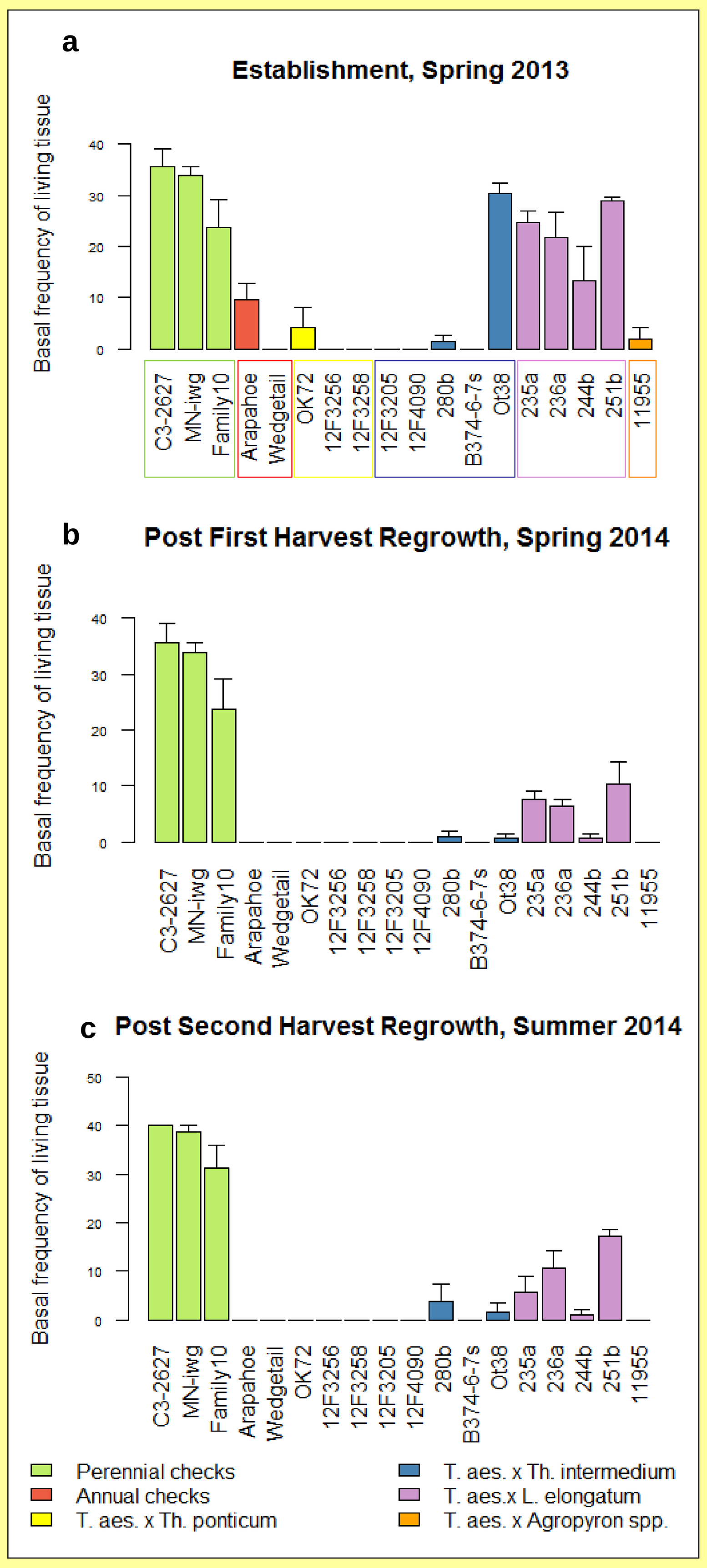

Figure 5. Basal frequency of plant growth a) after first winter in the establishment year, b) after first grain harvest, and c) after second grain harvest. Basal frequency is measured as number of 2.5cm blocks in 1m plot with adjacent living shoots or tillers. Error bars represent standard error.

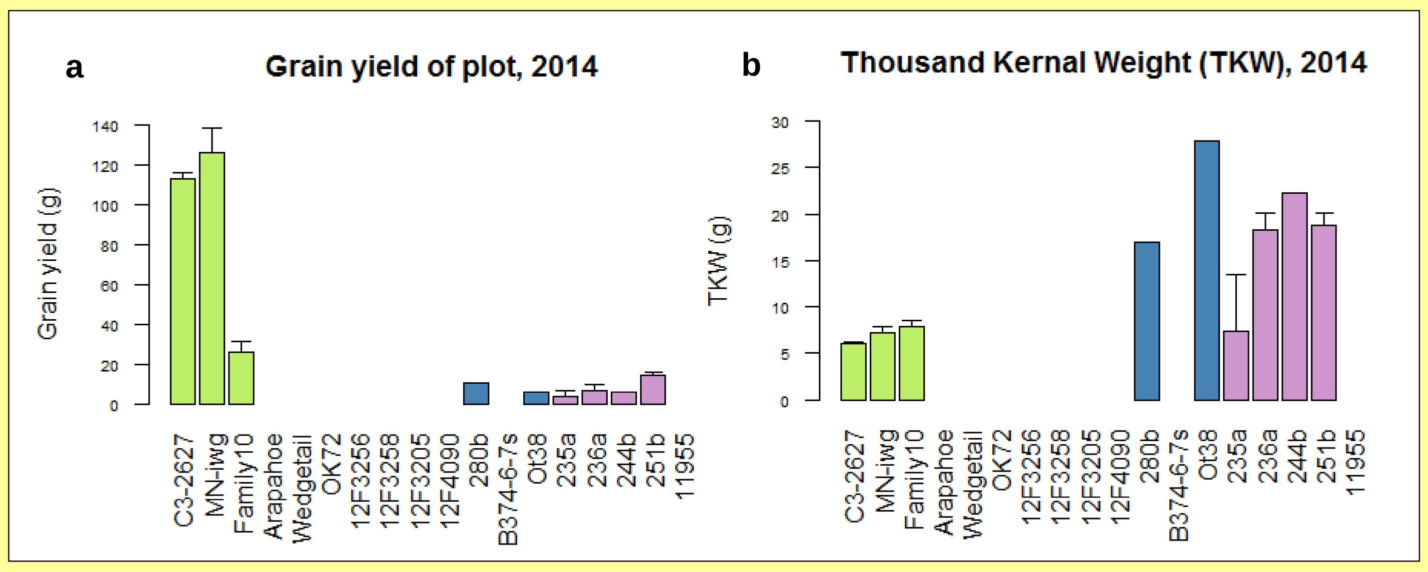

Figure 6. a) Grain yield of plot and b) TKW of lines surviving in 2014. Error bars represent standard error.

Yield and seed size 2013 and 2014

- Grain yield in 2014 was very low with a maximum of 16g in a 1m plot (Fig. 6a). The basal frequency of the plots were all less than 20 (50% coverage) (Fig. 5c) due to high within plot mortality, which contributed to poor yields.
- Perennial wheat thousand kernel weight (TKW) was relatively high compared to the perennial wheatgrass and mountain rye checks (Fig. 6b, Fig. 7a). Though the winter wheat planted did not survive in 2013, the TKW of the perennial wheat was comparable to the lower range of winter wheat. Four varieties commonly grown in Minnesota, ranged from 27-35g in TKW.
- Plot seed weight was higher in 2013 than 2014 for entries (Fig. 7b) due to a smaller number of surviving plants in 2014 as indicated by reduced basal frequency. Checks however had higher second year plot seed weight potentially due to better establishment and tillering, which is also consistent with increased plant height (Fig. 7b,c).
- Plot seed weight was positively correlated with both biomass and TKW in perennial wheat lines surviving in 2013 and 2014. Positive correlations between these traits are important for the development of a large seeded perennial grain crop.

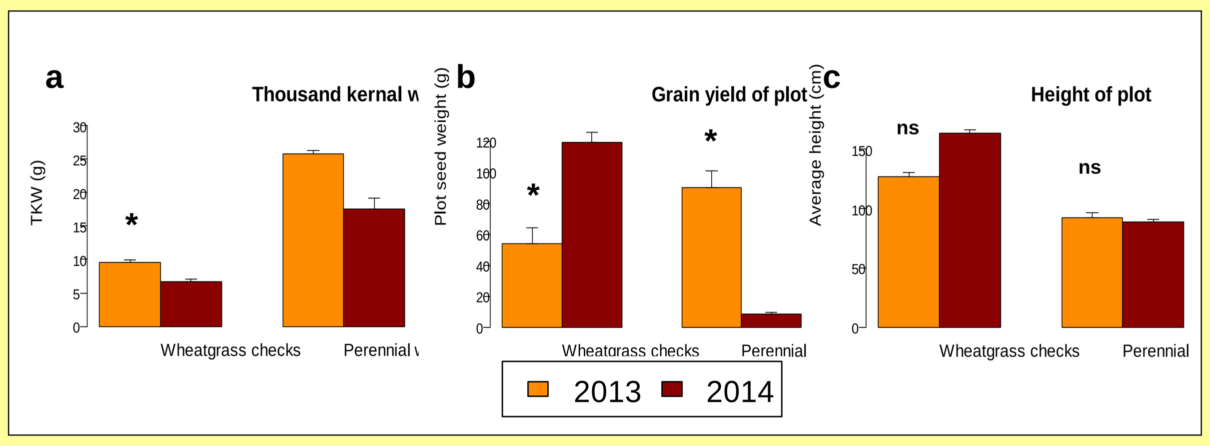

Figure 7 a) TKW, b) grain yield, and c) height in 2013 and 2014 for wheatgrass checks and experimental perennial wheat lines. Significance is indicated by (*) based on a Welch's two sample t test p<.05). Due to a significant genotype by environment interaction for TKW, 2013 and 2014 could not be compared for perennial wheat experimental entries.

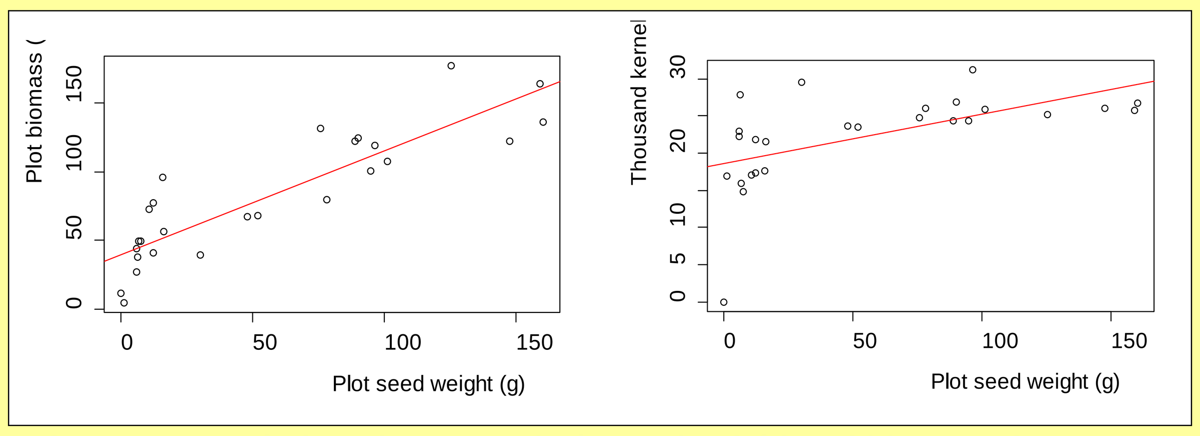

Figure 8. Correlations between a) plot grain yield and biomass (R^2 = .76, p<.001) and b) plot grain yield and TKW (R^2 = .29, p=.002) in perennial wheat lines in 2013 and 2014 that survived to produce grain in two years.

Preliminary Conclusions and Future Plans

- Winter survival is important in MN; lines surviving winter regrew and produced seed
- Perennial wheat derived from *Th. elongatum* and *Th. intermedium* demonstrate weak perenniality or winterhardiness in Minnesota
- High within plot mortality, inconsistent regrowth across replications, and declining second year yields indicate more robust perenniality is needed
- Understanding the mechanism controlling perenniality and the role of winterhardiness will be important for developing a consistent perennial wheat crop
- By comparing our observations with other locations, we hope to identify whether environmental factors contribute to regrowth and survival of perennial wheat worldwide

References

- Culman et al. 2013. *In Agronomy Journal.* 137:13–24.
- Glover, J.D. 2005. *In Renew. Agr. Food Syst*. 20:1–4.
- Turner and Rabalais. 2003. In *Bioscience*. 53:563–572.
- Turner et al. 2013. In *Crop Sci.*53:1994-2005.

Acknowledgements

- Dr. Guangdi Li, NSW DPI for compiling multi-site data.
- Susan Reynolds, Assistant Scientist UMN and Roger Caspers, Research Plot Coordinator UMN for assistance in managing pests and maintenance of the plots.