# Variation in rooting habit of potatoes: potential for improving resource capture.

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## ABSTRACT

Potatoes are important to Scottish agriculture but are also a major crop globally. Relative to cereals they are inefficient in their acquisition and utilization of water and minerals using a disproportionate amount of irrigation and fertilizer which conflicts with environmental protection measures and agricultural sustainability. We are screening potato cultivars for root traits associated with resource capture to develop an understanding of their genetic control. The present study was undertaken to assess variation in rooting traits of a range of potato genotypes including the European tetraploid potato (*S. tuberosum* Group Tuberosum), diploid Phureja potatoes (*S. tuberosum* Group Phureja) and Neotuberosum lines (selected from *S. tuberosum* Group Andigena) under field and glasshouse conditions. Significant differences in root number, length and surface area were found. Total root length per plant varied from 38m for the Tuberosum variety Pentland Dell to >100m for the Phureja variety Mayan Twilight. There was significant correlation between glasshouse and field measures; stolon root number from the glasshouse screen could be used to indicate total root length in the field. Our data demonstrate that there is significant variability in root characteristics amongst potato genotypes. In the future, molecular characterisation for genetic markers associated with improved rooting characteristics could enable resource capture improvement through genotypic and/or phenotypic selection of appropriate root traits and their expression in relevant commercial germplasm.

Keywords: *Solanum tuberosum,* Phureja, root, nutrient-use, sustainability, water-use.

## INTRODUCTION

Potato is the world’s number four crop in terms of production, making it the most important non-grain food crop. Potato crops are particularly sensitive to drought stress and consequently use a disproportionate amount of irrigation to maintain yield and tuber quality (Porter et al., 1999). Potato production in the UK, around 2.5% of arable land, consumes almost 50% of the irrigation water applied to field crops (White *et al*., 2005a).

In the UK, agriculture takes 4% of total water withdrawals. However, this is only a small fraction of the water required by crops, most of which is provided by rainfall. In the future, it is predicted that, although winters will be wetter, summers will be warmer and drier. This means that yields of field crops can only be maintained by increasing irrigation, and/or by the adoption of varieties or alternative crops suited to the drier summers (Morison *et al.,* 2008). Water loss to the environment could be reduced by promoting rapid ground cover and developing an effective root system for water uptake.

Potato crops receive high rates of fertilizer (N) and in combination with irrigation this contributes to leaching and groundwater contamination (Zebarth *et al*., 2004). Nitrogen utilization efficiency in commercial potato cultivars has been shown to decrease with increased N availability and cultivars vary in N-uptake and utilization efficiencies (Zebarth *et al.*, 2004). Potato root systems are also known to be inefficient in phosphorus uptake especially at low concentrations (Dechassa *et al.,* 2003, White *et al.,* 2005a,).

Genetic variation in WUE has been demonstrated in other major crops, using carbon isotope discrimination (Farquhar & Richards, 1984, Rebetzke *et al.,* 2002) while root architecture traits (such as root hairs, and lateral roots) have been seen to affect phosphorus uptake (White *et al.,* 2005b). There is therefore increased interest in using root traits as a selection criterion for improving yields (White *et al.,* 2005a; Lynch, 2007).

The aim of our research is to measure variation in rooting characteristics of potato genotypes, which come from the extensive collections of germplasm available to us at SCRI, in both field and glasshouse. This has enabled us to determine whether there is significant genotypic variation in important root traits and to establish a rapid glasshouse pot screen to enable assessment of large populations.

## METHODS

Five cultivars representing a range of maincrop group Tuberosum varieties with good disease resistance, two cultivars from the group “Neotuberosum” and one, Mayan Gold, from the diploid group “Phureja” were chosen. In the field trial four randomized blocks, surrounded by three “guard rows”, were grown (standard agronomic management) for 10 weeks and harvested just prior to tuberisation. Each plant was excavated by a team of three people who carefully dissected out the entire root system *in-situ*. Any roots which were broken were also collected and the plants taken to the laboratory for analysis (Fig 1). Each plant consisted of plantlets which were separated and each part of the plant was counted, measured, dried and weighed giving a range of 11 measures for dry weight of above and below ground plant parts, counts of plantlets, leaves, stolons, stolon roots, stolon node roots and basal roots. Each root class (including “extra roots” which had become detached and could not be classified) was preserved in 70% alcohol and measured using WinRHIZO software (Arsenault *et al.,* 1997).

A pot test was also carried out in the glasshouse using the same genotypes in a randomized block design with five replicates for each cultivar. The tubers were planted 10cm deep into 10 litre pots of sand and fed with modified Hoagland’s solution (2ml/kg/day). Potatoes were harvested two weeks after emergence and measures carried out exactly as with the field material.

All analyses were conducted in GENSTAT (VSN International, Heml Hempstead, UK) using ANOVA to assess variation by cultivar. Simple linear regression was used to look for dependent variables from each data set and correlation was used to look for patterns in the data and relationships between the pot and field measures. Multivariate principal component analysis was also carried out on the both field and pot datasets.

## RESULTS and DISCUSSION

There was a significant difference in the total root length among cultivars grown in the field (Fig.2. P=0.001) (mean of 4 reps plus standard errors of the means). Pentland Dell had significantly shorter roots than Cara and Golden Wonder (Gp Tuberosum), Neotuberosum 145 and Mayan Gold (Gp Phureja). There was a significant interaction between root length and number of roots (P<0.001).

Root thickness and distribution also varied significantly among cultivars with the Phureja line (Mayan Gold) having the longest (Fig.2) and thinnest roots (P <0.001) (based on ratio of stolon root no with stolon root weight). Surface areas of both stolon roots (P=0.013) and basal roots

(P=0.05) varied significantly with cultivar. There was also a significant difference in the number of stolon roots (P=0.017) and basal roots (P=0.002) amongst the cultivars with the Phureja line, Mayan Gold, having significantly more of both root classes. In addition, significant differences in the relative proportions of basal to stolon roots was apparent with the Phureja line, Mayan Gold, having the largest proportion of basal roots compared to the other cultivars tested (P=0.008) suggesting potential genetic differences in resource partitioning.

By repeating the experiment in the glasshouse we found good correlation between many of the variable rooting characters identified in the field and the measurements taken from two week old plants grown in pots in the glasshouse, such as number of stolon roots (pot) and total root length (field) (Fig.3 (Pot, means of 5 reps; Field means of 4 reps) R=0.832; P=0.005).

Principal component (PC) analysis, based on correlation, of all the field measures (above and below ground) demonstrated that "size" was responsible for PC1 (45% of the variation) with total root weight and number of roots having the highest loadings. PC1 scores varied significantly with cultivar (P=0.006). On the second component there was a negative correlation between stolon roots and basal roots (PC2 explained 14% of the variation). The same relationships were found in the glasshouse data where number of roots had the greatest influence on the PC1 score (35%) and basal and stolon root parameters were separated in PC2 (21% of the variation). PC1 and PC2 scores varied significantly with cultivar (PC1:P=0.001; PC2:P=0.002). Mean PC1 scores from the glasshouse screen were plotted against mean PC1 scores from field (Fig. 4).

Rooting characters therefore appear to have significant heritable variability (as they vary more between than within cultivar). In the future, we will look for relationships between these characteristics and other important breeding traits such as nutrient use efficiency, water use efficiency and final yield.

The experiments described here will be repeated to include a larger range of both Group Tuberosum and Group Phureja lines. The next screen will also include the parent lines of the mapping populations available at SCRI and from the Commonwealth Potato Collection.

We have demonstrated that there is significant variation in rooting characteristics amongst cultivars of potato and that this is predictable in a relatively rapid glasshouse screen. By applying this technique to available mapping populations we hope to identify markers which segregate with important rooting characteristics. This will aid selection of cultivars with improved resource capture efficiency thereby improving sustainability in the agricultural systems of the future.

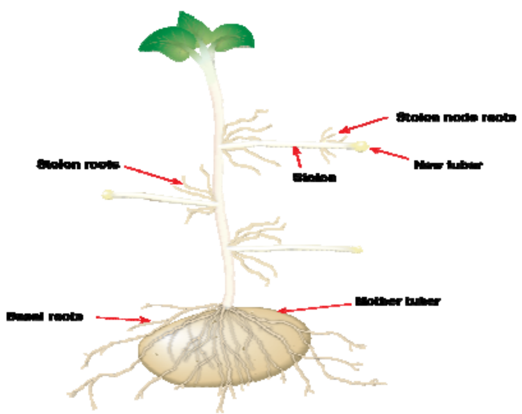


Figure 1. Schematic diagram of potato plant explaining the nomenclature for roots sampled in this paper.

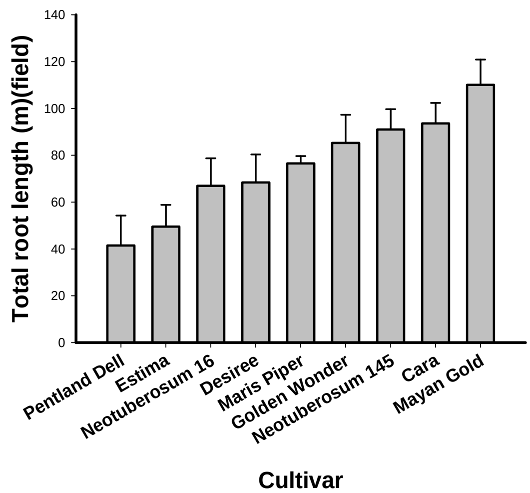


Figure 2. Total root length varied by cultivar.

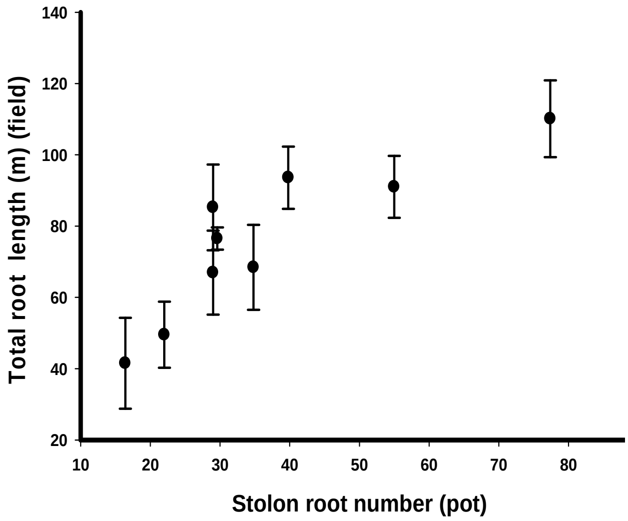


Figure 3. Stolon root number in the pot (glasshouse screen) correlated with total root length in the field.

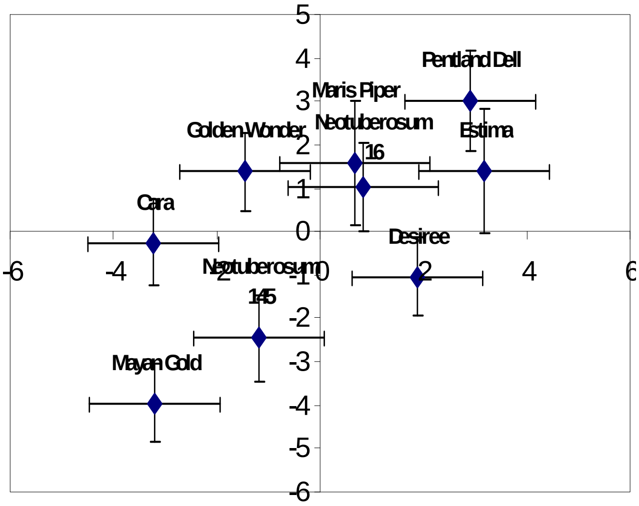


Figure 4. Mean PC1 scores (Field) plotted against mean PC1 scores (Pot) plus standard errors of the means.

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