Root architecture in potato: potential for improving resource capture and QTL mapping.

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Introduction

Global warming and climate change will impact agriculture across the world and crop production will become more vulnerable under future climates, which include competition for water resources and an increase in temperature. Potato, the world's most widely grown tuber crop and the third crop in terms of world food production, is a relatively sensitive crop in terms of both yield and quality, under limited water supply.

Potato is also considered to be inefficient in resource acquisition, using a disproportionate amount of water and fertilizer, which conflicts with environmental protection measures and agricultural sustainability. Previous studies in other crops have demonstrated that root architecture plays an important role in plant development and good root architecture improves the capacity to absorb water and nutrient and provides higher tolerance to abiotic and biotic stress factors (Fita et al, 2006). Plants which have large root-soil interfaces (e.g. longer roots or more surface area) are likely to be more efficient in capturing certain resources.

Aim

As little is known about the genetics of the rooting habit of the potato, this study was undertaken to measure the variation in rooting traits of a range of genotypes grown in the field and will help to evaluate genetic differences in cultivars/accessions of potatoes for water use efficiency (WUE).

Material and methods

Twenty eight broad range of potato genotypes consisting of the European tetraploid potato (*S. tuberosum* Gp Tuberosum) and stocks of Andean origin derived from the Commonwealth Potato Collection (*S. tuberosum* Gp Phureja, and Neotuberosum clones selected from *S. tuberosum* Gp Andigena) were sown in four replicate blocks (Figure 1).

Figure 1: Replicate field trial at Gourdie, Dundee.

Tubers were sown in field conditions and roots were excavated with care being taken that root system remains intact (Figure 2). Once excavated the root system was separated into stolon roots, basal roots, stolon node roots and extra roots (Figure 3).

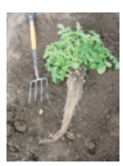

Figure 2: Harvested potato plant with intact root system.

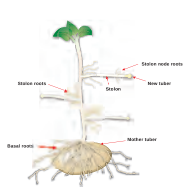

Figure 3: Categorisation of potato root system for further analysis.

Root types were scanned and the images analysed using Winrhizo software (Figure 4 and 5) which provided total length, surface area and average diameter of the roots.

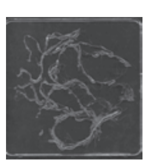

Figure 4: Scanned root system

Morphological measurements include number, length and weight of these categorised roots along with plant characteristics e.g. number and dry weight of shoots, leaves, stolons and tubers.

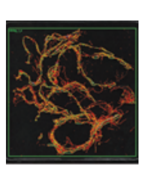

Figure 5: Analysis of scanned root system using Winrhizo software.

Analysis was done using Minitab and data is presented as the mean of the 4 replicates taking into account the effect of the person recording the measurements and also the time of harvest.

Results

Analysis of Variance for Total root length (cm)

	Source	df	Adj. SS	Adj. MS	F ratio	p-value
Covariate	Date Processed	1	[illegible]	[illegible]	19.13	<0.001
Covariate	Numeric recorder	1	228717	228717	0.01	0.904
Main Effect	Potato Cultivar	27	731668096	27100226	1.75	0.031
	Replicate Error	73	1132132841	15508669		

Table 1: Analysis of Variance representing significant difference between potato cultivars for total root length.

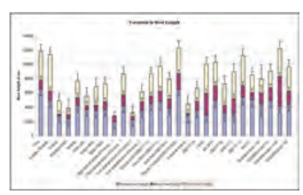

Figure 6: Variation in length of Stolon, Basal and Extra roots. Note: The error bars for stolon root length have been shown in downward direction.

Step	1	2	3	4	5
Constant	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tuber weight (g)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T-Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P-Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Replicate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T-Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P-Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Date Processed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T-Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P-Value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Basal root length (cm)		[illegible]	[illegible]	[illegible]	[illegible]
T-Value		[illegible]	[illegible]	[illegible]	[illegible]
P-Value		[illegible]	[illegible]	[illegible]	[illegible]
Basal Root Average Diam (mm)			[illegible]	[illegible]	[illegible]
T-Value			[illegible]	[illegible]	[illegible]
P-Value			[illegible]	[illegible]	[illegible]
No of basal roots				[illegible]	[illegible]
T-Value				[illegible]	[illegible]
P-Value				[illegible]	[illegible]
Extra root length (cm)					[illegible]
T-Value					[illegible]
P-Value					[illegible]
S	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
R-Sq	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
R-Sq(adjusted)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mallows Cp	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2: Results based on stepwise regression after considering 18 predictors consisting of Stolon, Basal and Extra root characteristics (Alpha to enter and remove: 0.15).

Figure 6 shows that variation among root characteristics exists among Tuberosum, Neotuberosum and Phureja. There was significant difference between cultivars for total root length (Table1, Figure 6) with between cultivar variance accounting for 23.30 % variation of Stolon root length, 22.66% of Basal root length and 12.55% of Extra root length.

Stepwise regression demonstrates that Basal root characteristics (length, number and diameter) account for most of the variation the cultivars after adjusting for mother tuber weight, recorder and date of processing (Table 2)

Significant variation exists between cultivars for number of stolons, number of leaves and other morphological traits (Figure 7).

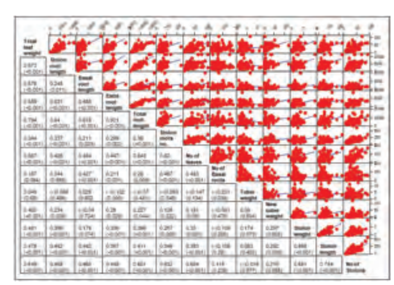

Figure 7: Matrix plot between different morphological traits together with their correlation. (Note: The probabilities are shown in brackets)

Results also show strong correlations between above ground morphological traits and root characteristics. For e.g. Number of leaves and weight of leaves with Root length and number of roots (Figure 7).

Solanum tuberosum exhibit high correlation between root number and root length than *S.phureja* cultivars which represent high variability (Figure 8).

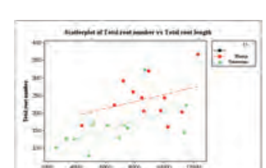

Figure 8: Scatterplot representing relationship between root number and root length in *S. tuberosum* and *S. phureja* cultivars. Regression equation for *S. tuberosum*

Conclusion

The principal outcome suggests that resource capture might be improved through selection of appropriate root traits and will assist in the investigation of mapping populations and other populations at SCRI to map genes associated with environmentally sustainable production

References:
Fita, A., B. Picó, and F. Nuez, 2006: Implications of the genetics of root structure in melon breeding. J. Amer. Soc. Hort. Sci. **131**, 372–379.