Selecting vigorous plants in the nursery: useful or useless?

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Abstract

In breeding population varieties, selection based on *per se* performance of spaced plants is less effective than selection for performance of their offspring would be. This holds especially true for complex traits like biomass production. Nevertheless, many breeders use ratings of biomass from spaced plants as a selection criterion. Based on historical data from the Agroscope forage crop breeding programme, we analysed correlations between *per se* performance of spaced plants in a polycross and performance of their half-sib progeny as assessed in seeded rows. Correlations between plant *per se* and offspring vigour ($r_{P,O}$), showed high variation among the different polycrosses analysed. Values of $r_{P,O}$ ranged from positive to negative, with mean values being close to zero for all species. A significance at the 5% level could not be attested for most of the parent-offspring comparisons, partly attributed to a low number of plants per polycross. The inconsistent correlation patterns are likely caused by data character (scoring data), comparison levels (single plants vs swards), different plant materials and the nature of the trait itself (vigour as an omnium-gatherum of plant height and amount of leaves and stems). Breeders should not rely too much on selecting spaced plants based on their vigour.

Keywords: forage crops, spaced plant, *per se* performance, sward, offspring performance

Introduction

The efficiency of a forage crop breeding programme is described by the continuous and stable improvement of desired traits in the breeding pool. Measuring this success is often difficult, due partly to complex inheritance patterns, and biotic and abiotic factors, which mask a plant's potential performance (Resende *et al.*, 2013). Repeated scorings for different traits are an instrument to unravel a plant's actual fitness. Based on that, superior plants are selected to enhance parental plants for polycross installations. However, the selection of single plants is only reasonable if it improves breeding progress. Thereby, plant vigour is preferred as a selection criterion, because it supposedly summarizes a plant's excellence and is phenotypically correlated. However, it is a complex trait and the transmission of good vigour from selected plants to their progeny is difficult to predict. The assessment of the usefulness of selection could be complicated by the standard breeding method, e.g. parental plants were cultivated and evaluated as single plants, but the performance of their corresponding offspring will be evaluated in swards. It has been reported that correlations between performance of spaced plants and their offspring grown in swards are weak (Elgersma, 1990; Waldron *et al.*, 2008). Consequently, breeding progress is attenuated by two dilemmas: for complex traits, the parent-offspring correlation might be weak and the evaluation system with comparisons of spaced plants to plants grown in swards has proved to be of low validity in previous studies. Therefore, the present study aimed to scrutinize which parent-offspring correlations are present during one important step in the selection cycle. So far, to the best of our knowledge, this is the first report about such correlations in forage crops, based on long-term breeding data over a wide range of species.

Materials and methods

Phenotypic data of different forage grass species (Table 1) were analysed for *per se* performance of spaced plants in polycrosses (PC) installed between 2000 and 2015 and performance of their half-sib progenies grown in seeded rows (SR) in trials installed between 2002 and 2017. Experimental and observational units in PC consisted of plots of 2 to 4 plants of the same genotype. Each genotype was replicated onto 4 plots, arranged in a randomized complete block design. PC were planted in autumn of year 1 and screened

Table 1. Summary of correlations between plant *per se* and offspring performance ($r_{P,O}$) for plant vigour at heading of first growth ($V1_P$ and $V1_O$, respectively) in different forage grasses.[1]

Species	n_{Tot}	n_{Sig}	$n_{Sig, Pos}$	Points per correlation			$r_{P,O}$		
				min	max	mean	min	max	mean
Lolium perenne, 4n	20	4	2	6	15	10.2	-0.75	0.82	0.10
Lolium perenne, 2n	19	2	2	4	15	7.5	-0.63	0.80	0.14
Lolium multiflorum, 4n	11	0	0	10	23	14.3	-0.56	0.51	-0.02
Lolium multiflorum, 2n	13	0	0	7	22	12.9	-0.36	0.58	0.07
Lolium hybridum, 4n	24	2	2	5	25	12.1	-0.53	0.64	0.05
Lolium hybridum, 2n	5	0	0	6	10	8.4	-0.31	0.44	0.10
Festuca pratensis, 2n	18	2	1	7	25	10.6	-0.68	0.84	0.08
Festuca arundinacea	4	0	0	7	9	8.5	-0.45	-0.09	-0.27
Dactylis glomerata	6	1	1	7	13	9.3	-0.46	0.94	0.31
Festuca rubra	3	0	0	8	16	12.0	-0.34	0.43	-0.08

[1] Parameters n_{Tot}, n_{Sig} and $n_{Sig,Pos}$ give the number of total, significant and significantly positive correlations, respectively.

for vigour of the first growth in the subsequent season ($V1_P$, assessment at heading date in year 2). Seeds of PC were harvested separately per genotype in year 2 and were used for sowing SR trials in spring of year 3, whereby each PC resulted in one SR trial. SR trials were installed at one Swiss location, either at the site of Oensingen (47.284 °N, 7.733 °E), Zürich-Reckenholz (47.428 °N, 8.521 °E) or Ellighausen (47.609, 9.139) with 4 to 8 replicates per half-sib family. Experimental and observational units consisted of 2.5 m length rows. SR trials were screened for vigour in the establishment year ($V0_O$, assessed in autumn of year 3), early vigour in the first main season ($EV1_O$, assessment in April of year 4) and vigour of the first cut of the first main season ($V1_O$, assessment at heading date of year 4). For subsequent analysis, mean values of *per se* performance from PC trials and offspring performance from SR trials were calculated for each parental genotype. PC and their corresponding SR trials were only included if overlapping data were available for 4 or more genotypes. In total, the dataset comprised 123 pairs of PC and SR trials from 10 different species-ploidy combinations (Table 1). Spearman rank correlation coefficients between *per se* and offspring performance ($r_{P,O}$) and their significances were calculated for each pair of a PC and SR trial.

Results and discussion

Only low numbers of significant correlations were observed between *per se* performance of spaced plants in PC and their half-sib offspring grown in SR (Table 1). A broad range of values for $r_{P,O}$ was observed, of which the significant ones were mostly positive (Table 1, comparison of n_{Sig} and $n_{Sig, Pos}$). No general differences between species or ploidy-levels could be detected, whereby average $r_{P,O}$ per species was close to zero. Correlations of $V1_P$ with other traits assessed in rows (e.g. $V0_O$, $EV1_O$) were generally lower (data not shown) and are not presented. The low number of significant correlations between parent and offspring performance was rather unexpected, likely having a multifactorial background. The small numbers of plants per polycross is one aspect that has contributed to the low number of significant correlations, as the statistical power to detect these is limited. Statistical power is also impeded by the fact that PC and SR trials were performed in only one environment, giving a less precise estimate of the true genotypic *per se* and offspring value. Furthermore, the simplification of vigour to a scoring number from 1 to 9 could have biased the analysis.

Beside statistical issues, the comparison of spaced plants and row installations itself is precarious due to different environmental conditions. Spaced plants are at an advantage relative to row plants regarding competition for space, nutrients, water and light. It is expected that the performance of plants grown in

swards exhibit half of the performance of spaced plants because genetic correlations between competitive and non-competitive impact is less than 1 (Casler and Van Santen, 2010). Reports from literature showed similar poor spaced plant-sward correlations to ours, with r=0.37 in *Festuca arundinacea* or r=0.6 in *Trifolium repens* (Resende *et al.*, 2013).

Furthermore, trait genetic architecture and heritability of a trait also give an impression about the success of selection. Vigour traits are highly complex and are determined by many genes, so variability in the breeding pool is essential to gain improvement. Heritability for such traits associated with fitness are considered to be low and the parent-offspring regression even lower (Wray and Visscher, 2008). In our data, spaced plants in PC already underwent strong selection pressure in the nursery and show less variability, which might have further reduced r_{PO}. Furthermore, parental plants in PC were already of higher age (up to 5 years) and might have been influenced by different factors (e.g. viruses). Such age effects might have additionally reduced correlation with their relatively young (1 year) offspring grown in SR trials.

Conclusion

The present study illustrates that a direct comparison of spaced plants to their offspring in rows or swards is difficult, as their correlation is reduced by different factors (spaced plant – sward, parent – offspring). Whereas plant *per se* vigour might be inevitable for use as a selection criterion when starting with a large population in the nursery, its effectiveness is questionable for use in pre-selected plants that have been transplanted to clonal rows. If possible, such older plants in clonal rows should be selected based on their offspring performance. To do so, pre-selected plants could be polycrossed already in the nursery and their half-sib offspring could be grown in seeded rows parallel to the parental plants being in clonal rows. The inclusion of genomic selection procedures would simplify selection of such pre-selected plants based on their breeding value and improve the success of a breeding programme.

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