Short communication. Decision on germplasm choice to apply breeding within a local population of common vetch is affected by crowding

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Abstract

The value of a population as a potential gene pool on which to apply selection may be severely underestimated under competition conditions because of the negative correlation of competitive versus yielding ability. To address this issue, a vetch (Vicia sativa) local population along with a control cultivar was evaluated at densities ranging from 1.15 to 25 plants m$^{-2}$. A hyperbolic increasing pattern as density declined was found for both grain and biomass yield. Nevertheless, at the highest density the control cultivar performance exceeded the population, whereas at the lowest density the opposite happened. The results were attributed to the heterogeneity of the population versus the homogeneity of the cultivar combined with the aforementioned negative relationship. It was concluded that severe crowding undervalues the potential of a population because plants representing high yielders cannot exhibit this capacity due to their competitive disadvantage. On the other side, the absence of competition optimizes the yield expression of individual plants. Therefore, absence of competition is recommended as the optimal condition to evaluate populations and make the right decision on the most promising one for breeding.

Additional key words: competitive ability; genetic heterogeneity; local population; Vicia sativa; yielding ability.

Resumen

Comunicación corta. La decisión sobre la elección de germoplasma para la mejora de una población local de veza común está afectada por el grado de densidad de siembra

El valor de una población, en el conjunto de sus genes potenciales sobre los que aplicar la selección, podría subestimarse de forma importante en condiciones de competencia, debido a la correlación negativa de la capacidad competitiva frente a la capacidad de producción. Para solucionar este problema, se evaluó una población local de veza (Vicia sativa) junto con un cultivar comercial como control, a densidades que oscilan desde 1,15 hasta 25 plantas m$^{-2}$. Se encontró, tanto en producción de grano como de biomasa, un patrón de aumento hiperbólico según iba disminuyendo la densidad. A mayor densidad, el comportamiento del cultivar control fue superior a la población, mientras que a menor densidad ocurrió lo contrario. Los resultados se atribuyeron a la heterogeneidad de la población vs. la homogeneidad del cultivar, combinado con la correlación negativa antes mencionada. Se concluye que las siembras a mayor densidad disminuyen el potencial de una población, porque las plantas muy productivas no llegan a exhibir su capacidad potencial debido a la desventaja competitiva. Por otro lado, la ausencia de competitividad optimiza la expresión de la productividad en plantas individuales. Por tanto, para optimizar la evaluación de las poblaciones para mejora y tomar decisiones correctas, se recomienda la ausencia de competitividad sobre las poblaciones más prometedoras.

Palabras clave adicionales: capacidad competitiva; capacidad de producción; heterogeneidad genética; poblaciones locales; Vicia sativa.
Germplasm that comprises individual plants representing genotypes potentially able to evolve into improved pure-line cultivars is deemed an essential and necessary precondition in plant breeding. In this sense, traditionally cultivated and locally adapted farmer varieties, the so-called local populations or landraces, might include valuable variability in agronomic traits that can be incorporated into new cultivars (Newton et al., 2010). Consequently, the determinant of success in accomplishing progress through selection is the choice of the most promising population as starting material.

In breeding new cultivars, the level of production should always be taken into consideration regardless of the particular agronomic trait(s) targeted. However, the yielding ability of a genotype is controlled by different genes than its competitive ability and the two characters are negatively correlated (Fasoula, 1990; Fasoula & Fasoula, 1997, 2002; Janick, 1999; Pan et al., 2003; Fasoula & Tokatlidis, 2012). Hence, the capacity of a particular genotype to yield highly may be masked when the population is evaluated under competition conditions. To address this issue, a vetch (Vicia sativa L.) local population along with a control cultivar was evaluated for single-plant grain and total biomass yield across the density range of 1.15 to 25 plants m$^{-2}$, in order to assess the crowding level that optimizes decision on germplasm choice for breeding aiming to develop high-yielding pure-line cultivars.

The primary material of the study was an unregistered population, obtained from a private seed-producing company (Zouliamis Seeds, Greece). On account of its adoption by farmers in the islands of East Aegean Sea in Greece, this population was assumed to consist of useful variability of agronomic interest. For comparison purposes, foundation seed of the cultivar ‘Alexandros’, provided by the Fodder Crops and Pastures Institute in Larissa, Greece, was also used. Experimentation was conducted under rain-fed conditions at the farm of the Democritus University of Thrace, Greece, Orestiada (41°29’N latitude, 26°32’E longitude, 24 m altitude) under low-input conditions (absence of any fertilization) on a silty clay soil with pH 7.6, organic matter 21.5 g kg$^{-1}$, N-NO$_3$ 10.1 mg kg$^{-1}$, P-Olsen 13.5 mg kg$^{-1}$ and K 171 mg kg$^{-1}$. During the critical growing period average monthly temperatures were 13.1, 19.6 and 23.5 °C for April, May and June, respectively, while the respective rainfall heights were 21.2, 18.6 and 37.2 mm. A field area of 850 m$^2$ was divided into six plots separated by corridors of 1.0 m in width, and sowing was applied on 12 March 2009 (Fig. 1). Each plot corresponded to a specific plant density and consisted of single-plant hills and included at least 260 of the population and 100 of the control cultivar. Four of the plots were established according to the non-replicated-0 (NR-0) honeycomb design (Fasoulas & Fasoula, 1995), with interplant distances of 1.0, 0.8, 0.6 and 0.4 m corresponding to densities of 1.15, 1.80, 3.20 and 7.22 plants m$^{-2}$, respectively, and the remaining two plots were planted at interplant distances of 0.2 × 0.4 m (12.5 plants m$^{-2}$) and 0.2 × 0.2 m (25 plants m$^{-2}$).

Figure 1. Arrangement of the six plots in the experimental area. Four plots were established according to the non-replicated-0 (NR-0) honeycomb design at interplant distances of 1.0, 0.8, 0.6 and 0.4 m corresponding to densities of 1.15, 1.80, 3.20 and 7.22 plants m$^{-2}$, respectively, and the remaining two plots were planted at interplant distances of 0.2 × 0.4 m (12.5 plants m$^{-2}$) and 0.2 × 0.2 m (25 plants m$^{-2}$).
leaving the plants to air dry for a month. The mean values were compared by the t-test for independent samples and different standard deviations, using Cochran’s approximation (Snedecor & Cochran, 1967).

The results showed the rational negative relationship between density and grain yield per plant, i.e., as density declined the excessive (hyperbolic) increasing pattern of yield fitted best in both germplasm cases (Fig. 2a). The grain yield per plant weighted lowest at the highest density (25 plants m–2) and highest at the lowest density (1.15 plants m–2). Moreover, at the highest density the control cultivar yielded by 29% higher compared to the population (6.50 vs 5.03 g plant–1), whereas at the lowest density the population yielded by 32% higher (12.1 vs 9.11 g plant–1). The means of the two kinds of germplasm were significantly different for these edge densities, but not for any of the rest of the densities. The relation between biomass yield per plant and density (Fig. 2b) was similar. Again, although the differences were not significant, the control cultivar produced 13% more biomass at the highest density and the population produced 16% more biomass at the lowest density.

In fact, the population succeeded in out yielding the control cultivar only when the density was lower than 3.2 plants m–2. At the lowest density, more likely to approximate absence of competition, apart from the highest yield, the difference between the two kinds of germplasm was also the greatest. This is in agreement with previous reports showing that the genetic composition of the two kinds of germplasm is taken into consideration along with the negative relationship between the competitive and yielding ability.

Thus, the control cultivar presents a fairly homogeneous germplasm. In this case, the effects of plant crowding at higher densities reflect an intra-genotype competition where individual plants strive equally for the limited resources. Lower densities soften this crowding impact allowing higher input consumption per plant and higher grain and biomass yield. Consequently, the less intense competition among genetically similar plants is the sole reason for the cultivar’s response to decreased crowding.

On the other hand, the population comprised plants representing various genotypes, so is characterized by genetic diversity. Within such a mixture of genotypes, a part of them may represent strong-competitors but low-yielders (Cy) at the one end and weak-competitors but high-yielders (cY) at the other (Fasoula, 1990; Fasoula & Fasoula, 1997, 2000; Tokatlidis et al., 2010; Fasoula & Tokatlidis, 2012). Kotzamanidis et al. (2009) also reported the highest grain yield per plant in barley at the lowest density (1.15 plants m–2).

The influence of density on yield was similar in the population and control cultivar for both grain and biomass. However, with density declining, the higher increasing rate in yield of the population allowed it to outperform the control cultivar at the lowest density, even though the population lagged behind the control cultivar at the highest density. These results make sense if the genetic composition of the two kinds of germplasm is taken into consideration along with the negative relationship between the competitive and yielding ability.

Figure 2. The density by genotype interaction inverted the rank of the two kinds of vetch germplasm at low against high densities for yield of both grain (a) and biomass (b). The impact is attributable to the negative association between the competitive and yielding ability.
tage over neighbouring cY plants, which justifies the low average performance of the population under high densities. As crowding decreases, the dominance of competitive advantage over yielding ability is reduced, so that the contribution of the cY plants to the average population value gradually increases. At very low densities, where any plant-to-plant interference for resources disappears (i.e., absence of competition), the role of the competitive ability is negligible. Hence, the cY plants fully express their high yield potential and boost the overall population performance.

In summary, these results provide further support to the generally believed view that the plant yield potential of a genotype is inversely associated with its competitive ability. More importantly, it is demonstrated that the value of a germplasm as a potential gene pool on which to apply breeding may be severely underestimated under competition conditions. Its actual value becomes apparent only when plant density is low enough to eliminate any plant-to-plant interference for resource utilization and erase the confounding effects of the competitive ability. In other words, absence of competition appears to be an imperative condition for exceptional genotypes to be revealed. It could be concluded therefore, that heterogeneous populations as a potential starting material for the development of new pure-line cultivars should be evaluated under ultra-low density conditions.

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