Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar
http://dx.doi.org/10.5424/sjar/2012103-641-11

Spanish Journal of Agricultural Research 2012 10(3), 752-755
ISSN: 1695-971-X
eISSN: 2171-9292

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

Th. Chatzoglou and I. S. Tokatlidis*

Department of Agricultural Development, Democritus University of Thrace. 682 00 Orestiada. Greece

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*.

*Corresponding author: itokatl@agro.duth.gr; itokatl@hotmail.com
Received: 07-12-11. Accepted: 21-06-12

Abbreviations used: Cy (strong-competitor and low-yielder); cY (weak-competitor and high-yielder).

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, 26º32'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

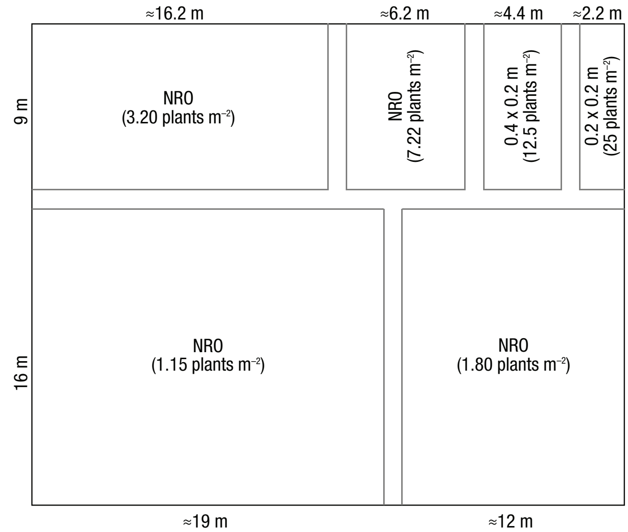

Figure 1. Arrangement of the six plots in the experimental area. Four plots were established according to the non-replicated-0 (NR-0) honeycomb design at interplant distances of 1.0, 0.8, 0.6 and 0.4 m corresponding to densities of 1.15, 1.80, 3.20 and 7.22 plants m^{-2}, respectively, and the remaining 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}).

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. The corresponding densities were 1.15, 1.80, 3.20 and 7.22 plants m^{-2} (*i.e.,* for d interplant distance, the area per plant equals to $d^2/\sqrt{3/2}$). The remaining two plots were planted at interplant distances of 0.2 m × 0.4 m (12.5 plants m^{-2}) and 0.2 m × 0.2 m (25 plants m^{-2}). In each plot, plants of the population and the control cultivar were sown at separate rows (*e.g.,* the 1.15 plants m^{-2} plot consisted of 16 rows involving only the population and of six rows consisting solely of the control cultivar). Complete weed control was obtained by manual hoeing. At harvest, entire above-ground plants were collected within separate sack-cloths. Both edge plants, as well as plants on the edge rows of either the population or control cultivar in each plot were excluded. In the occasional empty hill, all the neighbouring plants on the same row as well as the two adjacent rows were also ignored, so as to ensure that all the plants included in the calculation had been grown under the predefined for this plot density. The total biomass and grain per plant were weighted after

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 absence of competition maximizes phenotypic expression and differentiation (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.

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, 2002; Janick, 1999; Pan *et al.*, 2003; Fasoula & Tokatlidis, 2012). As a result, at high densities where inter-genotype competition prevails, plants share unequally the limited resources. Under severe crowding conditions, Cy plants have an advan-

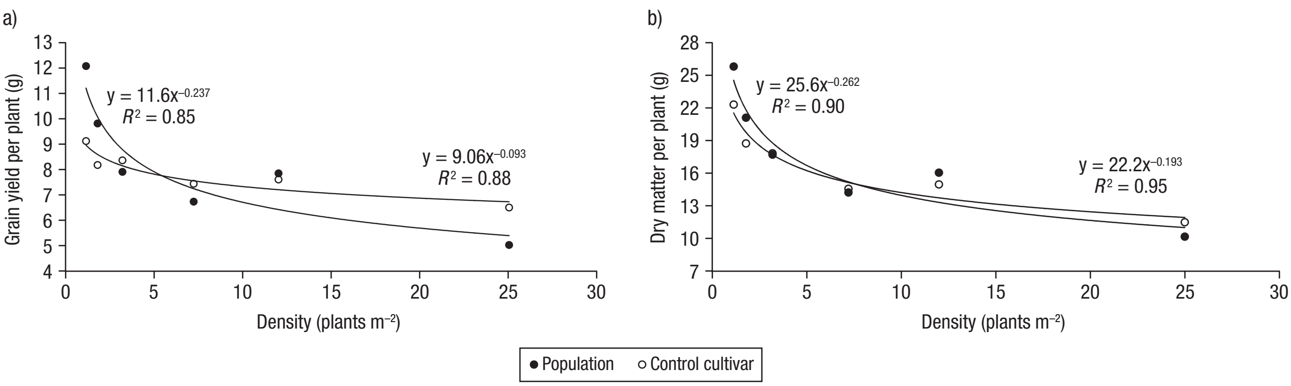

Figure 2. The density by genotype interaction inverted the rank of the two kinds of vetch germplasm at low against high densities for yield of both grain (a) and biomass (b). The impact is attributable to the negative association between the competitive and yielding ability.

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.

Acknowledgements

This research was funded by the Democritus University of Thrace, Greece.

References

Fasoula DA, 1990. Correlations between auto-, allo- and nill-competition and their implications in plant breeding. Euphytica 50: 57-62.

Fasoula DA, Fasoula VA, 1997. Competitive ability and plant breeding. Plant Breed Rev 14: 89-138.

Fasoula VA, Fasoula DA, 2002. Principles underlying genetic improvement for high and stable crop yield potential. Field Crop Res 75: 191-209.

Fasoula VA, Tokatlidis IS, 2012. Development of crop cultivars by honeycomb breeding. A review. Agron Sustain Dev 32: 161-180.

Fasoulas AC, Fasoula VA, 1995. Honeycomb selection designs. Plant Breed Rev 13: 87-139.

Janick J, 1999. Exploitation of heterosis: uniformity and stability. In: The genetics and exploitation of heterosis in crops (Coors JG, Pandey S, eds). ASA-CSSA-SSSA, Madison, WI, USA, pp: 319-333.

Kotzamanids ST, Lithourgidis AS, Roupakias DG, 2009. Short communication. Plant density effect on the individual plant to plant yield variability expressed as coefficient of variation in barley. Span J Agric Res 7(3): 607-610.

Newton AC, Akar T, Baresel JP, Bebeli PJ, Bettencourt E, Bladenopoulos KV, Czembor JH, Fasoula DA, Katsiotis A, Koutis K *et al.,* 2010. Cereal landraces for sustainable agriculture. A review. Agron Sustain Dev 30: 237-269.

Pan XY, Wang GX, Yang HM, Wei XP, 2003. Effect of water deficits on within-plot variability in growth and grain yield of spring wheat in northwest China. Field Crops Res 80: 195-205.

Snedecor GW, Cochran WG, 1967. Statistical methods, 6^{th} edn. Iowa St Univ Press, Ames, IA, USA.

Tokatldis IS, Has V, Mylonas I, Has I, Evgenidis G, Melidis V, Compandean A, Ninoy E, 2010. Density effects on environmental variance and expected response to selection in maize (*Zea mays* L.). Euphytica 174: 283-291.