STABILITY ANALYSIS FOR NUTRITIONAL CONTENTS (MINERALS AND VITAMIN C) ON 40 NATIVE POTATO CULTIVARS

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Introduction and objectives.- Zinc (Zn) and iron (Fe) are important micronutrients for human health for which widespread deficiency occurs in many regions of the world including South America. Breeding efforts for enriching potato tubers with more Zn and Fe are in progress at the International Potato Center (CIP). Knowledge of genotype by environment interaction effects on the micronutrient concentrations of different genotypes is needed to identify cultivars that show high and stable concentrations and to inform breeding and selection schemes. Stability analysis for micronutrient content has been applied to biofortification and varietal dissemination strategies. Thirty-three native potato varieties representing 5 taxonomic groups were evaluated to: (i) Assess the magnitude and nature of Genotype (G), Environment (E), and GxE interaction effects for Vitamin C (Ascorbic Acid), Zn and Fe concentrations in the tropical highlands of Peru; (ii) Study the contribution of soil fertility to the micronutrient content of potato tubers; (iii) Identify regions with similar expected performance of genotypes with respect to micronutrient density traits.

Materials and Methods.- Tubers were taken from plots grown in randomized complete block designs with three replications of one hill per plot in each of 6 sites of the central Peruvian Andes in 2010: Ccasapata (3765 m.a.s.l); Sotopampa (3754 m.a.s.l); Ccollpaccasa (4067 m.a.s.l); Conayca (4178 m.a.s.l), la Victoria (3265 m.a.s.l) and Rangra (3323 m.a.s.l). Well-matured tubers were harvested at 150 and 180 days. Samples were prepared and analysed for Fe and Zn by inductively coupled plasma-optical emission spectrophotometry (ICP-OES) using an ARL 3580B ICP (ARL, Switzerland) (Burgos et al., 2007) and for ascorbic acid concentrations (AA) by the spectrophotometric method of Egoville (Burgos et al., 2009).
Statistical analyses were performed using SAS software (SAS. 2003). ANOVA was performed using combined data for all environments. The Additive Main Effects and Multiplicative Interaction model (AMMI) was used for studying GXE interaction, examining genotypic yield stability and adaptation (Crossa et al., 2002). To understand the contribution of different soil nutrient variables, partial least squares analysis (PLS) was performed (Vargas et al.,1999). Maximum Entrophy (MAXENT) developed by Philips et al., (2006) was used to identify regions with statistically similar climates to the experimental sites in Peru. This analysis used global climatic datasets (monthly minimum temperature, monthly maximum temperature, monthly total rainfall, and 18 bioclim layers) from WorldClim at the highest space resolution of 30 seconds.
Results.- The contribution to variance of genotype, environment, GxE interaction and broad-sense heritability (H^2) and repeatability (R) estimates for nutrient concentration were as follows: Vitamin C (H^2=0.71 and R=2.98), Fe (H^2=0.36 and R=1.04) and Zn (H^2=0.18 and R=0.52). Fe and Zn thus showed lower heritability compared to Vitamin C, which is highly heritable and repeatable across environments, and therefore likely to be more responsive to selection. Fe and Zn concentrations were found to be significantly influenced by GxE interaction which contributed 26% and 16% to the total variation, respectively.

For vitamin C, despite the model showing concentrations to be unstable across environments, the values for 5 genotypes (CIP702815, CIP703168, CIP703280, CIP703825 and CIP704393) were above average in each of the environments. This does not occur in the case of Fe and Zn. Despite the non-significant correlation found between Fe and vitamin C concentrations, it was possible to identify four clones that had the highest combined values (CIP703825, CIP702815, CIP704481, and CIP703844). It is likely that these clones would demonstrate the highest bioavailable dietary iron based on high iron and vitamin C concentrations.

The concentration of manganese, Fe, Zn and Cu of the soil solution increases to various degrees with a fall in the pH or redox potential of soils (Marschner, 2006). For the Fe content of tubers, PLS determined that the environmental covariables pH, cation exchange capacity (CEC) and electrical conductivity (EC) were associated with factor 1, which explained a large portion of the GxE interaction, while Fe content and soil organic matter were negatively associated with factor 2. As for the Zn content of tubers, PLS determined that the environmental covariables pH, Zn soil content, CEC and EC were associated with factor 1, which explained a large portion of the GxE interaction, while soil organic matter was negatively associated with factor 2.

MAXENT identified regions with climates similar to the environments tested based on results of the AMMI stability model. For example: One map shows localities with similar climates in which clones that have broad adaptation can be expected to express their high contents of Vitamin C, Fe or Zn with a probability index above 50%. Other map shows localities with climates similar to Collpaccasa, to which clones CIP702453, CIP702736, CIP702815 and CIP703312 show specific adaptation and high Fe content with a probability index above 50%.

Discussion and conclusions.- The Fe and Zn concentrations of the genotypes were highly unstable with respect to production environments. This was reflected in low values for broad sense heritabilities of tuber Zn and Fe concentrations. The higher variability of tuber Zn content values suggest that in some locations genetic biofortification may need to be complemented with agronomic biofortification, such as the use of Zn fertilizer. The Fe and Zn concentrations of potato tubers were found to be significantly influenced by environmental conditions, particularly the availability of soluble soil micronutrients. Considering the complexity of the accumulation of Fe and Zn in potato tubers, the associated low heritability and the considerable environment and GxE interaction, progress in the genetic analysis of these traits is expected to be slower than that for some simpler traits. However, in spite of these challenges genetic gains in the concentration of Fe and Zn have been achieved. Higher GxE interaction and lower stability for Fe and Zn content values in potato suggest that an important step in breeding for enhanced concentration should be the testing of stability of Fe and Zn accumulation across selection processes and target environments, or a better understanding of environmental and management factors that influence the traits. Heterogeneity of the concentration of Fe or Zn in the soil can confound or mask genetic differences among genotypes, thereby preventing the identification of genotypes with genetically superior Fe and Zn content. It has been suggested that given the strong GxE interaction, screening in the course of breeding for enhanced micronutrient concentrations could be highly unreliable. Strategies to minimize the impact of GxE or heterogeneity include: (i) attention to experimental design (systematic use of controls, alpha lattice designs, and spatial analysis) and (ii) attention to trial management such as the use of Zn- containing fertilizer to try to homogenize soil Zn concentration. Models coupling geographic information system (GIS) with stability trials are powerful tools to identify regions with similar climates to predict the performance of genotypes across environments, and offer to increase the success of breeding, selection and dissemination of improved crops in international or regional breeding programs.

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