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Evaluation of Indian Potato Germplasm for Iron and Zinc Content

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Micronutrient deficiency affects more than half of the world's population especially in developing countries. Amongst micronutrients iron and zinc are the two major elements for human nutrition and their deficiency is commonly observed. Biofortification of food crops is an emerging area of research to overcome such mineral deficiencies. Potato has a priority claim for biofortification as it yields more nutritious food per unit area and time and may contribute significantly in meeting nutritional requirements of the population. Keeping this in view a breeding programme is initiated for which germplasm characterization was done. Forty-six potato germplasm with varying degree of flesh colour from white to yellow to violet were evaluated for iron and zinc content in raw and peeled tubers. The iron content ranged between14.90-67.13 mg/ kg (ppm) dry weight and zinc between 2.78-35.40 mg/kg (ppm) dry weight basis in tuber flesh. Significant and positive correlation between these two nutrients suggests that breeding varieties with high content of both these nutrients is feasible. Carotenoids content enhances the bioavailability of the micro nutrients but lack of correlation between tuber flesh colour index and nutrient concentration in the present study indicated that these traits are independent. The genotypes CP 1239, CP1435, CP1812, CP1983, CP1978, CP2067, CP2414, CP3443, CP3772 and CP4242 are promising as parental material for developing iron and zinc rich potato varieties.

Key Words: Micronutrient content, Potato germplasm, Tuber flesh

Introduction

Potato (*Solanum tuberosum* L.) is the third most important food crop following rice and wheat (Camire *et al*., 2009) and is increasing its hold in developing countries because of its price stability, high yield capacity and better nutritional properties (White *et al.*, 2012). The ability of potatoes in providing food and nutrition security has been given prime importance in today's era. China, the largest potato producer and holding 20 percent of the world total potato production has declared potato as food crop and targeted 50 percent of its extra food demand during the next 20 years to be met from this crop (http://www.cipotato.org/press-room/press- releases/feeding-the-future). India has the next rank and constitutes 10 percent of the global share. The per capita consumption of potatoes in India has reached to 20 kilogram (CPRI Vision document, 2050) but this is quite low than the world average of 32.60 kilogram (FAOSTAT, 2013). In India potatoes are consumed as vegetable crop and are considered as seasonal staple food crop at times of glut in the market (Scott and Suarez, 2011). The vegetarian pattern of food culture in India will keep potatoes as an important part of their diet even with rise in income (Pingali, 2006). Micronutrient deficiency contributes high rate of infant, children and women's mortality. The dietary intake of iron and zinc is often insufficient in diet based on cereals rich foods. Globally 3500 million people are vitamin A, iodine, iron or zinc deficient (Pfeiffer and McClafferty, 2007) causing hidden hunger. The role of iron is of oxygen carrier in human and is incorporated into the heme complex. Iron deficiency is prevalent in both developed and developing regions and the typical deficiency symptoms are pale skin, general fatigue, stunting of growth and vulnerability to infections. Zinc is part of several key enzymes and its deficiency is prevalent in the deprived populations feeding mainly on plant based foods causing poor brain development, hair loss, lesions on skin, diarrhoea, wastage of body tissues, weak eyesight, memory loss, taste and olfactory abnormalities.

Potato, declared as the hidden treasure, (International Year of Potato, 2008) is an important source of carbohydrates, vitamins, minerals and high biological value protein. Biofortification is the technique of breeding new varieties of better food value i.e. dense nutrients and phytonutrients concentrations. It is the genetic modification of plants aimed to enhance the concentration of some specific nutrient elements. To target the potato crop for nutrient biofortification, characterisation of germplasm is the basic step to

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know the range and nature of variations available. The literature cites significant variations (Burgos *et al*., 2007) with high heritability i.e. more genotypic influence on mineral content than environment for iron and zinc micronutrient concentrations. In addition to content, bioavailability of minerals is very important for absorption of nutrient element. This depends on the chemical form the nutrients is present and the presence of promoter and anti-nutrient factors. The absorption percent of potato iron is 10 percent and 25 percent of potato zinc (Bonierbale, 2014). This absorbed iron and zinc constitutes 50 and 40 percent, respectively of estimated average requirement. The low content of phytates and oxalates (inhibitor) while vice versa high ascorbic acid, b-carotene, protein cysteine and amino acids (promoter) content along with significant associations among both the elements strengthens the concept of iron and/or zinc biofortified potato varieties. Keeping this in view forty-six diverse flesh coloured potato germplasm of tuberosum background were analysed for iron and zinc content to find the variations for the traits and, thereby, genotype selection for mineral biofortification.

Materials and Methods

Freshly harvested tubers of forty-six potato germplasm (Table 1) were collected from the field germplasm repository of Central Potato Research Station, Kufri, Himachal Pradesh. The samples were derived from the plants grown under standard recommended production practice and non nutrient limiting conditions in summer season of 2015. The plot size was 4.8 m^2 with 4 rows of 2 m each and the row to row and plant to plant distance was 60×20 cm. The soil of the experimental field was acidic (pH 6.1) in reaction and the available micronutrients was high. All the samples (5 tubers per replication) were prepared in three replications. The samples were peeled (0.5 mm peel removed using standard food grade stainless steel knife), oven dried at 70 °C and finely powdered samples were analyzed for their iron and zinc content after acid digestion (nitric and perchloric) with an atomic absorption spectrophotometer (Model-Shimazdu-AA700). Data of the collected parameters were subjected to analysis of variance. Correlations among traits were studied using Pearson's correlation coefficient. The dendrogram was prepared in software XLSTAT version 2017 by calculating pair-wise genetic dissimilarity index following the method of Euclidean distance using Ward's minimum variance method (Ward, 1963).

Results and Discussion

Variations for Iron and Zinc Content

The Analysis of variance for iron and zinc content in varied coloured potato germplasm depicted significant variations ($p <0.05$). The range and mean values (given in parenthesis) for iron content were 14.90-67.13 ppm (32.44 ppm; Fig .1). In the previous reports the iron content in Indian potato varieties varied between 17.75 to 40.74 ppm and the average content was 27.53 ppm in dried tuber flesh (Dalamu *et al*., 2016) while in Indian

Table 1. List of germplasm and the source countries

CP Numbers (Variety Name)	Source region
CP 1497 (2814a(1), CP 1500 (2183c(2), CP 1527 (2403a(1), CP 1547 (Pentland Envoy), CP 1616 (835a(4)	United Kingdom
CP 1549 (Aspotet), CP 1555 (Pimpernelx 42No.174)	Norway
CP 2062 (Serrana), CP 2067 (ASN69-1), CP 2132 (Tollocan), CP 2378 (POOS.16), CP 2413 (Piratini), CP 2414 (CEZ69.1), CP 2416 (MEX 750826), CP 3443 (CIP 380474.6), CP 3479 (TS-10),CP 3486 (TS-15), CP 3493 (P-55.7), CP 3577 (E86.300), CP 3756 (LB-X), CP 3762 (CIP 392657.8), CP 3768 (CIP 393280.82), CP 3772 (CIP 393382.44), CP 3781 (CIP 385556.4), CP 3802 (WilaYari)	Peru
CP 1435 (Tedria), CP 1544 (Asoka), CP 1546 (Sirtema), CP 1978 (Amalfy), CP 3535 (Arinda)	Netherlands
CP 3167 (Perkoz)	Poland
CP 2012 (Rosita)	Mexico
CP 3917 (Hermes)	Austria
CP 1012(Unknown), CP 1239 (Unknown), CP 1315 (Unknown), CP 1317 (Unknown)	Unknown
CP 4242 (Bora Valley)	Korea
CP 1604 (B5052-7), CP 1817 (B 6038-1), CP 1890 (B 5698-8), CP 1945 (K 194-3), CP 3973 (Russet Burbank)	United States of America
CP 1812 (HYB.NO.20078), CP 1983 (49.540/2)	Germany
CP 1701 (Belle De Founteny)	France

potato genotypes constituting varieties and advanced stage hybrids the content ranged from 21 to 53 ppm (Trehan and Sharma, 1996).In reference to global scenario, CIP, Peru potato varieties had more narrower range of 11-30 ppm iron content (Bonierbale, 2014). Thus, the present germplasm collection had better iron content than those of varieties and advanced hybrids as till now the potato breeding was mainly focused on quantitative improvement. With the growing consumer awareness and preference, trend has been shifting towards quality breeding with respect to nutrient value along with yield advantage. The best performing genotypes for iron content in the descending order of content were CP 1435 (67.13 ppm), CP 3443 (62 ppm), CP 3772 (55.73 ppm), CP 1239 (52 ppm) and CP 2067 (50.20 ppm).

Zinc content varied from 2.78-35.40 ppm with mean value of 14.29 ppm (Fig 1). CP 3443, CP1978, CP1435, CP2067, CP1812 and CP1983 had the highest zinc content of 35.40, 27.18, 27.13, 26.71, 25.53 and 25.11 ppm, respectively. Indian potato varieties had mean zinc content of 15.29 ppm (9.54 to 21.00 ppm on dry weight basis in potato flesh; Dalamu *et al*., 2016) while the varieties and advanced hybrids had zinc content of 10 to 18 ppm (Trehan and Sharma, 1996). Similarly CIP potato varieties had 8-25 ppm zinc content (Bonierbale 2014). Though, the mean content of zinc in varieties and germplasm are somehow equivalent but the high zinc containing genotypes viz., CP 3443, CP1435 and CP2067 also having high iron content are the potential genotypes for breeding mineral rich potato varieties.

Variations for Tuber Flesh Colour Index

Xanthophylls group of carotenoids impart yellow colour to potato tuber flesh and has antioxidative properties and prevention of age-related macular degeneration. The flesh colour represented in three-digits code where the first digit is for predominant flesh colour, second digit for secondary flesh colour and the third digit for the distribution of the secondary flesh colour (Fig. 2a; Kumar *et al*., 2005) where 100 represents white flesh with no secondary colour, 200 is cream with no secondary colour, 300 is yellow-cream with no secondary colour, 400 is yellow with no secondary colour, 500 is red with no secondary colour and 600 is violet flesh with no secondary colour. The majority of germplasm lies in the range of white to yellow flesh colour (Fig. 2b) except for CP 4242, a purple/violet fleshed genotype. The CP Nos. 1547, 1544, 3768, 1527, 1435, 1317, 1978, 1604, 1239 and 2416 had yellow flesh colour.

Association among Iron, Zinc and Tuber Flesh Colour Index

The significant correlation between zinc content and iron content (r =0.69) insights the feasibility of breeding genotypes with both high iron and zinc content, however, this study relates to only one location and environment thus necessitates validation of association under varied edaphic and environmental conditions. Lack of significant correlation between tuber flesh colour index and iron and zinc content indicates that mineral content and flesh colour are independent traits. Yellowness of tuber flesh colour is an indicator of xanthophylls content and also reflects higher iron bioavailability (Bonierbale *et al.,* 2011). Thus, selection of yellow tuber fleshed germplasm with high iron content is the selection yardstick for breeding iron rich genotypes alongwith yield advantage, agronomic superiority and wider adaptability.

Cluster Analysis Based on Iron and Zinc Content

Cluster analysis of 46 germplasm based on iron and zinc content was performed by Ward's minimum variance method and a dendrogram was constructed as depicted in Figure 3. All the germplasm were resolved into three major clusters.

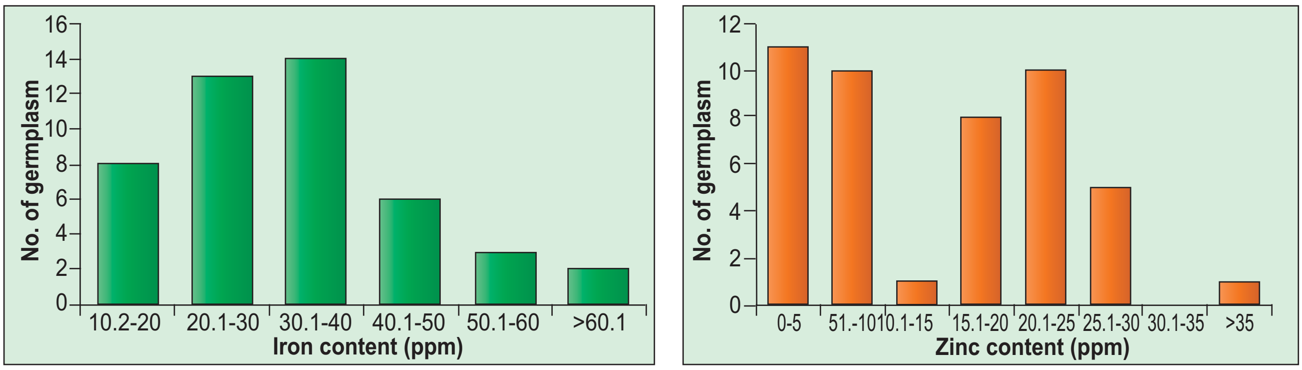

Fig. 1. Frequency distribution of Iron and Zinc content in 46 potato germplasm

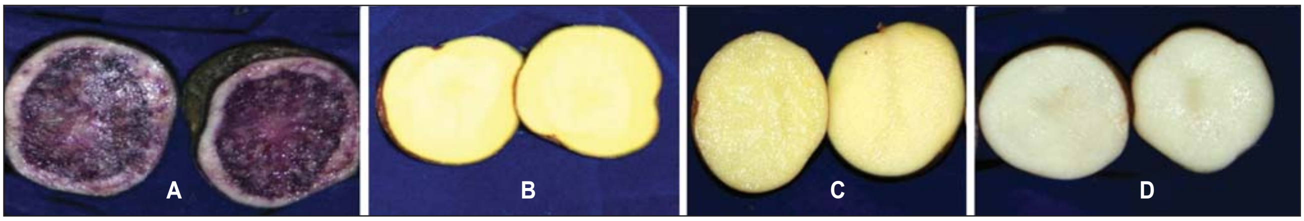

Fig. 2a. Potato tuber flesh colour (A) Violet/purple (B) Yellow (C) Cream (D) White

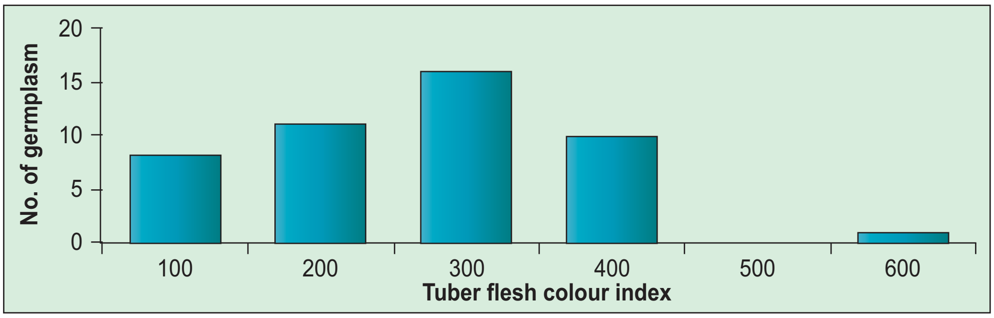

Fig. 2b. Frequency distribution of Tuber flesh colour index in 46 potato germplasm

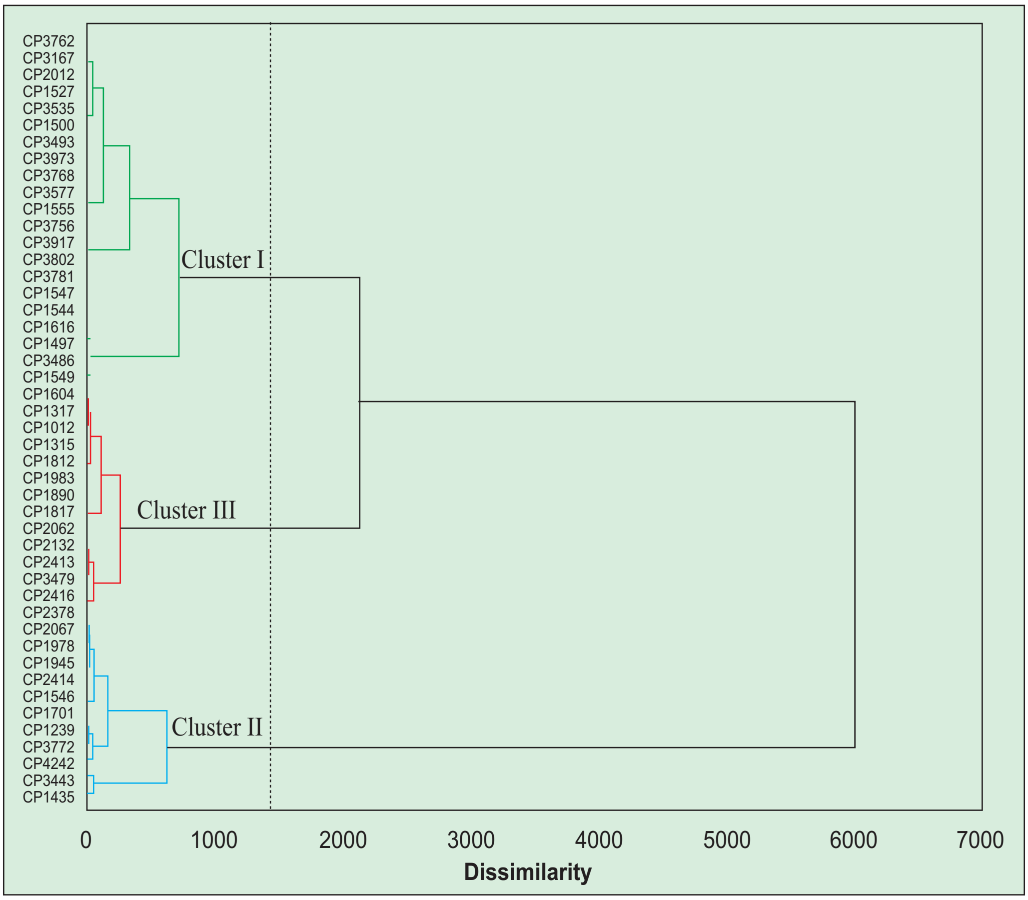

Fig. 3. Clustering of 46 potato germplasm based on Euclidean Distance

Cluster II constituting genotypes CP Nos. 1435, 2414, 4242, 3772, 1945, 1978, 2067, 1701, 1546, 3443 and 1239 had the highest iron (50 ppm) and zinc content (24.56 ppm) while cluster I comprising the maximum number of genotypes (21) had the least iron and zinc content of 24.53 and 5.14 ppm, respectively.

Conclusion

Genotypes CP 1239, CP1435, CP1812, CP1983, CP1978, CP2067, CP2414, CP3443, CP3772 and CP4242 with desirable zinc and iron content individually or in both were identified which will be useful for future breeding programme to develop nutritional superior potatoes.

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