Journal of Applied Botany and Food Quality 86, 99 - 103 (2013), DOI:10.5073/JABFQ.2013.086.014

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Mineral composition and their genetic variability analysis in eggplant *(Solanum melongena* L.) germplasm

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(Received July 2, 2013)

Summary

Eggplant, *Solanum melongena* L. is one of the most popular and major vegetable crops grown in South Asia and other parts of the world. It is an important source of plant-derived nutrients like minerals, available throughout the year and popular among the poor. Thirty two morphologically diverse eggplant germplasm accessions were analyzed for macro- and micro-minerals. Significant differences in the mineral content among the germplasm accessions were detected. Potassium and magnesium ranged from 177.19 to 274.48 mg and 6.25 to 18.34 mg/100 g fresh weight (FW), respectively. Copper, iron and zinc ranged from 0.024 to 0.178, 0.170 to 0.846 and 0.073 to 0.233 mg/100 g FW, respectively. Phenotypic co-efficient of variation and genotypic co-efficient of variation were high for the minerals studied except potassium. High broad sense heritability (84.44-97.07%) indicated the presence of additive gene effects. Significant positive correlation were found between zinc with potassium (r=0.397), magnesium (r=0.439) and copper (r=0.409). Overall, two germplasm accessions IC090785 and IC383102 have been identified as rich sources for all minerals studied, which could be utilized further in breeding programme for developing mineral-rich varieties of eggplant.

Introduction

Eggplant (*Solanum melongena* L.), also known as aubergine, brinjal, or guinea squash, is a vegetable crop, economically important, consumed throughout the world. It is native to the South East Asian region and was domesticated over 4000 years ago. Current evidence suggests that eggplant is native to India, with secondary centers of diversity in other parts of Southeast Asia and China (Swarup, 1995). The increased consumption of eggplant has been attributed to the increase in ethnic diversity and the greater awareness that diets rich in fruits and vegetables are linked to a lower mortality rate and incidence of diseases (Chen et al., 2007; Hasler et al., 1998). Eggplant is low in calories and has various macro- and micro-minerals which are beneficial for human health. Potassium is the abundant mineral present in the eggplant, ranged from 200 to 600 mg/100 g of fresh mater. Eggplant is also a rich source of magnesium, calcium and iron (Kowalski et al., 2003).

Minerals are present in all body tissues and fluids and their presence is necessary for the maintenance of certain physicochemical processes which are essential to life. Every form of living matter requires these minerals for their normal life processes. Deficiencies of micro-minerals are a major global health problem. More than 2 billion people in the world today are estimated to be deficient in key minerals, particularly, iron and zinc. This is particularly true in the developing world, where more than 40% of women are anaemic (WHO/FAO, 2001). Most of these people live in low income countries and are typically deficient in more than one micronutrient. Deficiencies occur when people do not have access to micronutrient-rich foods such as fruit, vegetables, animal products and fortified foods, usually because they are too expensive to buy or are locally unavailable.

Since, eggplant is an important source of plant-derived nutrients, available throughout the year and popular among the poor; there is an urgent call to carry out extensive research efforts to know its mineral composition and identify mineral rich germplasm. Although report on nutritional aspects and mineral content in the crop are available, there is no information regarding associations of mineral content and their genetic variability and heritability. Therefore, to fill this knowledge gap, the present investigation was undertaken to ascertain the mineral composition of different germplasm accessions of eggplant and to find out their heritability based on phenotypic and genotypic variation, which could be useful in qualitative improvement of the eggplant rich in mineral content.

Materials and methods

Eggplant samples

Thirty two eggplant germplasm accessions used in the present study were obtained from National Gene Bank, National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India. Seeds were sown in nursery on June, 2011 at NBPGR New Area Farm, Pusa Campus, New Delhi (77.15 °E longitude and 28.64 °N latitude) in semi-arid type of climate with temperatures ranging from 20 °C to 40 °C, average RH of 50% and rainfall ranging from 550 to 850 mm. The seeds were treated with Captan {cis-N [(trichloromethyl) thio]-4 cyclo hexane-1, 2-dicarboximide} to prevent soil-borne fungal diseases, mainly damping-off occurring in the nursery, and sown in nursery beds. One-month-old seedlings (about 15 cm in height) were transplanted in single row, each 6 m long, with 90 cm spacing between the rows and 60 cm between plants. A basal dose of 100 kg N, 80 kg P_2O_5, and 60 kg K_2O ha^{-1} was applied and top dressing with 40 kg N ha^{-1} was done 45 d after transplanting. Irrigation and hand weeding were performed whenever necessary. Five fruits per plant were harvested at marketable maturity stage. Three independent samples of each accession were analyzed and each replicate was processed independently. Fruits were hand rinsed under a stream of tap water to remove the dirt from fruit surface, then rinsed with double distilled water and gently blotted with paper towel to remove the water. Cleaned and surface-dried fruits were sliced longitudinally into small pieces representing the whole sample, and fresh weight (FW) was recorded. The samples were dried at 65 °C in a hot-air oven (Labco, India) for 72 h until constant dry weight (DW) was achieved, then ground into powder with a mechanical grinder for use in estimating mineral content.

Analytical methods

Moisture content was determined as 100 x (FW-DW / FW). Mineral content was estimated according to official analytical methods (AOAC, 1990) with atomic absorption spectrometer (AAS, model-Varian Spectra AA 220 FS, Varian Australia Pty Ltd, Australia) equipped with a D_2 lamp background correction system, and

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using an air-acetylene flame. Determinations were carried out in triplicate for each independent sample of each genotype. For the analysis of minerals, 5 g of dried ground sample were calcined in a Muffle furnace (Labco, India) at 450 °C for 2 h. Ash was moistened with double distilled water and 2-3 drops of concentrated HNO_3 (69%, GR Grade, Merck KGaA, Darmstadt, Germany) was added. Crucibles were again kept in muffle furnace at 450 °C for 30 min to complete ashing. The ash was then dissolved in 5 ml of concentrated HCl (37% GR Grade, Merck KGaA, Darmstadt, Germany). The mixture was heated until the first vapors appeared and 10 ml of double distilled water was added immediately. Then the solutions were filtered through quantitative ashless filter paper and the final volume was made up to 100 mL with double distilled water. The samples were analyzed using AAS calibrated with standards (CertiPUR grade, Merck KGaA, Darmstadt, Germany). AS-FRM (Food Reference Material) 14 (rice-2 for minerals) obtained from Institute of Nutrition, Mahidol University, Thailand was used as reference material to evaluate the analytical methods. Quality control for minerals were also checked using eggplant samples spiked and not spiked with known amount of standards of minerals analyzed. The detection limits for minerals were 3 µg/100 g for K; 0.3 µg/100 g for Mg; 3 µg/100 g for Cu; 6 µg/100 g for Fe and 1 µg/100 g for Zn.

Statistical analyses

All statistical analyses were performed using Statistical Analysis Software (SAS, 2009). Analysis of variance was carried out using PROC GLM to determine significant differences in macro- and micro-minerals among the eggplant germplasm accessions. Simple linear correlation analysis was performed to indicate the measure of correlation and strength of relationship between variables. Principal Component Analysis (PCA) using correlation matrix was performed to study the relative contribution of macro- and micro-minerals to the total variability in the eggplant germplasm accessions.

The phenotypic variation for each trait was partitioned into genetic factors and estimated according to JOHNSON et al. (1955):

σ^2_p=MSg/r; σ^2_g=(MSg-MSe)/r;

Where σ^2_p and σ^2_g are phenotypic variance and genotypic variance, respectively; MSg, MSe and r are mean squares of accessions, mean squares error and number of replications respectively.

Phenotypic (PCV) and genotypic coefficient of variation (GCV), heritability (h^2) in broad sense and genetic advance (GA) were estimated according to SINGH and CHAUDHARY (1985) as given below:

$$\text{GCV} = \frac{\sqrt{\sigma_g^2}}{\bar{x}} \times 100$$

$$\text{PCV} = \frac{\sqrt{\sigma_p^2}}{\bar{x}} \times 100$$

$$\text{Heritability}(h^2) = \frac{\sigma_g^2}{\sigma_p^2}$$

$$\text{Heritability}\,\% = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Expected genetic advance (GA) $= i\sigma_p h^2$

GA (%) $= (\text{GA}/\bar{x}) \times 100$

where, σ^2_p: phenotypic variance, σ^2_g: genotypic variance, $\bar{x}$: general mean of character, i: standardized selection differential, a constant (2.06) and σ_p: phenotypic standard deviation ($\sqrt{\sigma_p^2}$).

Results and discussions

The results revealed that there were significant differences with wide variability among the 32 eggplant germplasm accessions with respect to moisture, potassium, magnesium, copper, iron and zinc content (Tab. 1). The moisture content ranged from 90.86% to 95.04% with the mean value of 92.72%.

Potassium: IC413648 had the highest potassium content (274.48 mg/100 g), followed by IC090940 (270.86 mg/100 g) and IC261772 (265.91 mg/100 g). The lowest amount of potassium was found in IC112744 (177.19 mg/100 g). The mean potassium content for 32 germplasm accessions was 231.83±4.08 mg/100 g. The phenotypic coefficient of variation for potassium (9.95%) was least among all the minerals analyzed.

Magnesium: The magnesium content averaged 12.73±0.58 mg/100 g, the highest being found in IC104083 (18.34 mg/100 g) followed by IC112993 (18.31 mg/100 g). The coefficient of variation for magnesium (25.65%) was second lowest among all the minerals analyzed. Out of 32 germplasm accessions, 16 showed above-average values for magnesium content.

Copper: The copper content among the germplasm accessions studied ranged from 0.024 - 0.178 mg/100 g with an average of 0.093±0.01 mg/100 g. Fifteen germplasm accessions showed above-average mean values for copper content. Highest amount of copper was found in IC545854, while lowest amount in IC104083. The coefficient of variation (44.33%) for copper was maximum than all other minerals studied.

Iron: The highest amount of iron was found in IC090785 (0.846 mg/100 g), followed by IC112516-1 (0.733 mg/100 g) and IC074209 (0.686 mg/100 g). The mean iron content in 32 germplasm accessions was 0.498±0.01 mg/100 g and 17 germplasm accessions showed values higher than the mean value. The coefficient of variability for iron (30.12%) was second highest among all the minerals analyzed.

Zinc: Zinc content among the germplasm accessions ranged from 0.073 mg/100 g (IC090981) to 0.233 mg/100 g (IC383102) with an average mean of 0.158±0.01 mg/100 g. Out of 32 eggplant germplasm accessions, 17 germplasm accessions contained more than the mean value.

The levels of various macro- and micro-minerals studied among the 32 eggplant germplasm accessions were consistent with the levels reported earlier (ALVI et al., 2003; RAIGON et al., 2008). Variability plays an important role in crop breeding programs. The extent of diversity in crop determines the limits of selection for improvement. In any crop-breeding program, it is prerequisite to have a large variation in the material at the hand of breeder. The present study revealed that there was a wide variability among the eggplant germplasm accessions with respect to their mineral content.

Minerals are important constituents of human diet as they serve as co-factors for many physiological and metabolic processes. Potassium is the most abundant intracellular cation in the body and contributes to intracellular osmolality. Enzymes involved in glycolysis and oxidative phosphorylation are potassium-dependent (HADDY, 1987). Magnesium is an important co-factor of many regulatory enzymes, particularly the kinases, and is fundamental in the energy transfer reactions involving high energy compounds like ATP and creatine phosphate and thus muscle contraction (TILLMAN and SEMPLE, 1988) and pregnancy-induced hypertension and pre-eclampsia (ROBERT et al., 2003). Adequate dietary intake of iron,

Tab. 1: Mean values, standard error (SE), least significant differences (LSD; *P*=0.05) and Phenotypic Coefficient of variation (CV %) for moisture (%), macro- and micro-mineral composition (mg/100 g fresh weight) in 32 eggplant germplasm accessions studied

Germplasm	Moisture %	K	Mg	Cu	Fe	Zn
IC074209	91.79	247.84	7.98	0.060	0.686	0.161
IC089888	92.40	236.13	13.61	0.064	0.247	0.131
IC090053	91.84	210.29	10.76	0.129	0.498	0.159
IC090785	93.27	255.81	16.13	0.071	0.846	0.211
IC090806	92.52	220.91	11.44	0.093	0.425	0.101
IC090938	93.35	231.81	13.28	0.125	0.526	0.168
IC090940	92.85	270.86	9.29	0.088	0.560	0.161
IC090981	92.69	203.18	6.39	0.048	0.531	0.073
IC104083	94.08	236.70	18.34	0.024	0.602	0.190
IC111066-2	93.28	222.60	12.47	0.090	0.382	0.112
IC111416	92.75	228.49	11.46	0.063	0.475	0.157
IC111439	92.26	218.73	14.29	0.108	0.382	0.201
IC112516-1	93.14	221.39	6.25	0.056	0.733	0.084
IC112732	93.38	223.78	12.69	0.126	0.483	0.152
IC112744	93.54	177.19	10.81	0.115	0.389	0.132
IC112991	92.23	204.29	14.97	0.035	0.608	0.156
IC112993	90.86	212.36	18.31	0.108	0.395	0.119
IC127063	95.04	208.40	7.31	0.060	0.630	0.081
IC261772	92.82	265.91	14.42	0.051	0.296	0.154
IC261793	93.82	252.45	14.47	0.054	0.170	0.093
IC285125	92.65	250.20	12.72	0.144	0.616	0.177
IC310884	92.93	240.31	15.07	0.096	0.525	0.112
IC333527	92.08	217.24	9.93	0.078	0.404	0.165
IC354140	93.03	230.17	15.39	0.158	0.548	0.207
IC354517	92.13	242.17	13.11	0.057	0.648	0.224
IC354597	92.39	184.87	9.49	0.044	0.223	0.189
IC354604	92.67	243.89	10.76	0.108	0.405	0.188
IC354612	92.31	237.54	12.65	0.150	0.589	0.192
IC383102	92.76	258.06	16.02	0.171	0.634	0.233
IC413648	91.97	274.48	13.74	0.127	0.439	0.228
IC544884	91.18	244.78	15.72	0.107	0.464	0.140
IC545854	93.16	245.83	18.14	0.178	0.593	0.204
Mean	92.72	231.83	12.73	0.093	0.498	0.158
SE	0.14	4.08	0.58	0.007	0.027	0.008
LSD	0.001	7.45	0.91	0.01	0.10	0.02
PCV (%)	0.88	9.95	25.65	44.33	30.12	28.30

zinc, and copper is essential to human health. More than 2 billion people worldwide are anaemic, and this can be mainly attributed to iron deficiency. Iron is an essential component of body systems involved in the utilization of oxygen. Iron deficiency during childhood and adolescence impairs physical and mental development (WHO/FAO, 2001). Zinc is required for protein and carbohydrate metabolism, immune system, wound healing, growth and vision. Inadequate zinc intake can result in retarded growth, delayed wound healing, reduced immune system, loss of taste sensation and dermatitis (UMETA et al., 2000). The adult body contains approximately about 80 mg copper mainly stored in liver, followed by brain and muscle. Cytochrome C oxidase, superoxide dismutase (SOD), lysyl oxidase and tyrosine oxidase are the major enzymes which require Cu for their activity. Deficiency signs of copper include anemia, vascular complications, osteoporosis and neurological manifestations. The relative significance of copper was more than that of ascorbic acid in iron-deficiency anaemia (CHIPLONKAR et al., 2003).

Tab. 2: Linear correlation (r) between moisture, macro and micro-minerals of 32 eggplant germplasm accessions studied

	K	Mg	Cu	Fe	Zn
Moisture %	-0.053	-0.123	-0.147	0.135	-0.217
K		0.335	0.199	0.196	**0.397***
Mg			0.312	-0.044	**0.439***
Cu				0.109	**0.409***
Fe					0.231

*Significance at P=0.05

All the significant correlations, *viz.* zinc with potassium, magnesium and iron (r=0.397, 0.439 and 0.429, respectively, at $P < 0.05$) were found to be positive (Tab. 2). Such correlation analysis will facilitate selection of germplasm with improved nutritional quality, as selection for one trait leads to selection of genetically correlated traits (Wricke and Weber, 1986). However, correlation analysis alone could not give a complete picture of interrelations because it considers only two minerals at a time, regardless of the interrelationship with other minerals in the set of data. Hence, PCA was carried out to understand the underlying interrelationships in the whole set of data and to select the best linear combination of minerals that explains the largest proportion of the variation in the data set.

PCA revealed that the first three principal components (PCs) together governed 79.27% of the total variability (Tab. 3). The first principal component (PC1) accounting for 42.45% of the total variation and all the macro- and micro-minerals studied had relatively positive weight on this component. PC2 and PC3 accounting for 20.80 and 15.99% of the total variation, respectively. In all the three principal components, the coefficients corresponding to iron and zinc were positive and consistent, whereas potassium is positive in first two PCs. Since, iron and zinc followed by potassium in PC1 and PC2 (eigen value >1) accounted for more of the variation in the set of data than other minerals, they were the most appropriate to use in the preliminary grouping of the 32 eggplant germplasm accessions evaluated in this study.

The characters like minerals are generally quantitative in nature and exhibit considerable degree of interaction with gene. Thus, it becomes necessary to compute variability present in the material and its partitioning into genotypic and phenotypic effects. In the present study, the values of phenotypic coefficient of variability (PCV) were greater than the corresponding genotypic coefficient of variability (GCV) values, though in many cases the differences were very less (Tab. 4). Copper and iron followed by zinc showed high PCV and GCV values, while potassium showed low PCV and GCV values. The broad sense heritability for micro- and macro-minerals was more than 84% with maximum of 97.06% for magnesium followed by potassium. The expected genetic advance as percentage of mean ranged from 19.69 to 85.96%. Maximum genetic gain was observed for copper (85.96%) followed by iron (55.39%). Potassium showed low genetic gain (19.69%).

Little difference between phenotypic coefficient of variation and genotypic coefficient of variation and high estimates of heritability (broad sense) for macro- and micro-minerals indicates that the differences between accessions for mineral contents were genetic in nature. The genotypic coefficients of variation were less than that of the phenotypic coefficients of variation for all the characters indicating the influence of non-additive gene action (Shukla et al., 2005). Because the coefficient of variation measures the magnitude of variability present in the population, selection from population with such coefficient of variation values is very likely to be effective in improvement of the minerals studied. High broad sense heritability values indicated the predominance of additive gene action in the expression of these traits and can be improved through individual plant selection.

Variability alone is not of much help in determining the heritable portion of variation. The amount of gain expected from a selection depends on heritability and genetic advance in a trait. Knowledge of heritability of a character is important as it indicates the possibility and extent to which improvement is possible through selection (Robinson et al., 1949). However, high heritability alone is not enough to make sufficient improvement through selection generally in advance generations unless accompanied by substantial amount of genetic advance (Johnson et al., 1955). The expected genetic advance is a function of selection intensity, phenotypic variance, and heritability and measures the differences between the mean genotypic values of the original population from which the progeny is selected. It has been emphasized that genetic gain should be considered along with heritability in coherent selection breeding programmes. It is considered that if a trait is governed by nonadditive gene action it may give high heritability but low genetic advance, which limits the scope for improvement through selection, whereas if it is governed by additive gene action, heritability and genetic advance would be high, consequently substantial gain can be achieved through selection. Heritability estimates along with

Tab. 3: Average range of variation and component scores of the first 3 principal components in 32 eggplant germplasm accessions studied

Minerals studied	Range	Mean	SD	First 3 principal components		
				PC1	PC2	PC3
Potassium	177.19-274.48	231.83	23.06	0.461	0.135	-0.641
Magnesium	6.25-18.34	12.73	3.26	0.476	-0.452	-0.192
Copper	0.024-0.178	0.093	0.04	0.443	-0.134	0.731
Iron	0.170-0.846	0.498	0.15	0.222	0.871	0.110
Zinc	0.073-0.233	0.158	0.05	0.561	0.033	0.067
Variance %						
Component				42.27	20.90	15.95
Cumulative				42.27	63.17	79.13

Tab. 4: Estimates of mean squares, variance components and heritability for various minerals in 32 eggplant germplasm accessions studied

Mineral	Selection parameters							
	Mean	MS	σ^2_p	σ^2_g	PCV (%)	GCV (%)	h^2B (%)	GA (%)
K	231.831	1595.3450	531.7818	510.9721	9.95	9.75	96.09	19.69
Mg	12.729	31.9707	10.6569	10.3440	25.65	25.27	97.06	51.28
Cu	0.093	0.0051	0.0017	0.0016	44.33	43.01	94.12	85.96
Fe	0.498	0.0675	0.0225	0.0190	30.12	27.68	84.44	52.40
Zn	0.158	0.0060	0.0020	0.0019	28.30	27.59	95.00	55.39

MS: mean squares, $\sigma 2p$: phenotypic variance, σ2g: genotypic variance, PCV: Phenotypic coefficient of variation, GCV: Genotypic coefficient of variation, h^2B (%): broad sense heritability, GA (%): Genetic advance.

genetic advance are more useful in predicting the resultant effect for the selection of the best individuals from a population. The heritability and genetic advance values were high for copper, zinc and followed by iron, suggests that these traits are under genetic control and significant improvement can be obtained for these traits.

Within in the range of eggplant germplasm used in this study, there exist substantial genetic variability and heritability in the minerals studied to warrant selection in the eggplant accessions for improvement. The level of genetic variability observed for different minerals would be useful for breeding program for developing mineral rich varieties of eggplant. The high genetic variance components and heritability estimates couple with significantly positive correlation could be used as selection criteria for identification of mineral rich eggplant germplasm. Two germplasm accessions, IC090785 and IC383102 have been identified as rich sources for all minerals studied. Hence, these two accessions could be utilized further in breeding programme for developing mineral-rich varieties of eggplant

Acknowledgement
We are grateful to Director, National Bureau of Plant Genetic Resources, New Delhi, India for constant support and encouragement in conducting this study.

References

ALVI, S., KHAN, K.M., SHEIKH, M.A., SHAHID, M., 2003: Effect of peeling and cooking on nutrients in vegetables. Pak. J. Nutr. 2, 189-191.

AOAC, 1990: Official methods of the Association of Official Analytical Chemists. 15th Edition. Washington, DC, USA.

CHEN, L., VIGNEAULT, C., VIJAYA RAGHAVAN, G.S., KUBOW, S., 2007: Importance of the phytochemical contents of fruits and vegetables to human health. Stewart Posthar. Rev. 3, 1-5.

CHIPLONKAR, S.A., AGTE, V.V., MENGALE, S.S., 2003: Relative importance of micronutrient deficiencies in iron deficiency anemia. Nutr. Res 23, 1355-1367.

HADDY, F.J., 1987: Dietary sodium and potassium in the genesis, therapy, and prevention of hypertension. J. Am. Coll. Nutr. 6, 261-270.

HASLER, C.M., 1998: Functional foods: Their role in disease prevention and health promotion. Food Technol. 52, 63-70.

JOHNSON, H.W., ROBINSON, H.F., COMSTOCK, R.E., 1955: Estimates of genetic and environmental variability in soybean. Agron. J. 47, 314-318.

KOWALSKI, R., KOWALSKA, G., WIERCINSKI, J., 2003: Chemical composition of fruits of three eggplant (*Solanum melongena* L.) cultivars. Fol. Hort. 15, 89-95.

RAIGON, M.D., PROHENS, J., MUNOZ-FALCON, J.E., NUEZ, F., 2008: Comparison of eggplant landraces and commercial varieties for fruit content of phenolics, minerals, dry matter and protein. J. Food Comp. Anal. 21, 370-376.

ROBERT, J.M., BALK, J.L., BODNAR, L.M., BELIZÁN, J.M., BERGEL, E., MARTINEZ, A., 2003: Nutrient involvement in preeclampsia. J. Nutr. 133, 1684-1692.

ROBINSON, H.F., COMSTOCK, R.E., HARVEY, P.H., 1949: Estimates of heritability and the degree of dominance in corn. Agron. J. 41, 353-359.

SAS, 2009: Statistical Analysis Software system, Version 9.2. SAS Institute, Cary, NC, USA.

SHUKLA, S., BHARGAVA, A., CHATTERJEE, A., SRIVASTAVA, J., SINGH, N., SINGH, S.P., 2005: Mineral profile and variability in vegetable Amaranth (*Amaranthus tricolor*). Plant Foods Hum. Nutr. 61, 23-28.

SINGH, R.K., CHAUDHARY, B.D., 1985: Biometrical methods in quantitative genetic analysis. New Delhi, Kalyani, 318.

SWARUP, V., 1995: Genetic resources and breeding of aubergine (*Solaum melongena* L.). Acta Hort. 412, 71-79.

TILLMAN, D.W., SEMPLE, P.F., 1988: Calcium and magnesium in essential hypertension. Clin. Sci. 75, 395-402.

UMETA, M., WEST, C.E., HAIDAR, J., DEURENBERG, P., HAUTVAST, J., J, J.A., 2000: Zinc supplementation and stunted infants in Ethiopia: a randomised controlled trial. Lancet. 355, 2021-2026.

WHO/FAO, 2001: Human vitamin and mineral requirements. Report of a Joint FAO/WHO Expert Consultation; Geneva, Switzerland.

WRICKE, G., WEBER, W., 1986: Quantitative genetics and selection in plant breeding. W. de Gruyter, Berlin, Germany.

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