Mineral profiling of common bean (*Phaseolus vulgaris* L.) germplasm

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**ABSTRACT**

Common bean (*Phaseolus vulgaris* L.) is the most important edible food legume in the world. It represents 50% of grain legumes consumed worldwide. It is a rich source of protein, complex carbohydrates, poly unsaturated fatty acids (linoleic acid and lenolenic acid), fibre, vitamins and minerals. So far as, minerals are concerned, they are not only important for plant growth and development but for animal growth and development spatially humans as well. In present study, we have evaluated 84 genotypes of common bean for various mineral elements and we have observed wide variation in mineral contents and have also identified the genotypes with high mineral contents. The presence of variability in mineral content among the genotypes could be used as an asset by plant molecular breeders for biofortification of common bean which in turn can be used to address the problem of malnutrition in developing and under developed countries, where common bean is a major source of protein.

**Key words:** Biofortification, Common bean, Germplasm, Malnutrition, Minerals.

**INTRODUCTION**

Common bean (*Phaseolus vulgaris* L.) is the most important edible food legume in the world. It represents 50% of grain legumes consumed worldwide (Talukder et al., 2010). It is a rich source of protein, complex carbohydrates, poly unsaturated fatty acids (linoleic acid and lenolenic acid), fibre, vitamins and minerals (Sathe et al., 1984). It serves 15% of the protein and 30% of the caloric requirement to the world’s population (Mc Connell et al., 2010). Being a good and cheap source of protein and energy, it is a food of choice in developing countries, as it can combat malnutrition and hunger-related problems (Reyes-Mareno et al., 1993). It is not only an energy legume but has anti-diabetic and anti-cancer activities (Camara et al., 2013).

As the domestication of common bean had occurred independently in South America and Central America/Mexico, so there are two different domesticated gene pools, the Andean and Middle American, respectively (De bouck et al., 1993). It has been reported that common bean genotype of Middle American origin has higher mineral content in seeds than the genotypes of Andean origin. Small (16.9g per 100 seeds) navy bean seeds of Middle American origin contain on an average, 90% more calcium than the large kidney bean seeds (47.8g per 100 seeds) belonging to Andean origin (Moraghan and Grafton, 1997). Twenty nine common bean genotypes were assessed by Talukder et al. (2010), for zinc and iron contents, and it was observed that the cultivars of Middle American genotypes had 16.1 and 11.3% more zinc and iron respectively, as compared to that of Andean genotypes. Advances in common bean genomics, such as the availability of complete sequenced genome (Schmutz et al., 2014), have resulted in the development of common bean as a model crop for understanding genetics of some other related and important legumes that includes other members of papilinoid legumes like, cowpea, pigeon pea. Therefore, a better understanding of common bean genome will also facilitate a better comprehension of other important legumes through comparative genomics studies.

In present study, various common bean genotypes, were studied for concentration of mineral elements viz. boron (B), phosphorus (P), sulphur (S), copper (Cu), manganese (Mn), magnesium (Mg) and calcium (Ca). These element are not only essential for plant growth (http://soils.wisc.edu/facstaff/barak/soilscience326/listofel.htm) but are beneficial for human health as well (http://www.fao.org/docrep/field/003/ab470e/ab470e06.htm).

Boron is required by plants for development and strengthening of cell wall, cell division, fruit and seed

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Table 1: Elemental status of 84 common bean genotypes.

| Sample name | B (mg kg⁻¹) | P (mg kg⁻¹) | S (mg kg⁻¹) | Cu (mg kg⁻¹) | Mn (mg kg⁻¹) | Mg (mg kg⁻¹) | Ca (mg kg⁻¹) |
|-------------|-------------|-------------|-------------|--------------|--------------|--------------|--------------|
| P-2         | 1.27±0.12   | 1895.74±0.23 | 1320±0.29   | 20.6±0.17    | 44.69±0.17   | 2144.58±0.29 | 2076.8±0.23 |
| P-3         | 1.45±0.06   | 1978.6±0.17  | 1183.39±0.17 | 11.8±0.13    | 71.23±0.13   | 1354.76±0.06 | 1612.86±0.06|
| P-10        | 1.13±0.06   | 1007.65±0.23 | 1241.71±0.23 | 10.4±0.20    | 38.69±0.06   | 1334.36±0.17 | 1733.25±0.14|
| P-11        | 3.12±0.12   | 1765.43±0.06 | 1123.84±0.12 | 23.1±0.12    | 79.38±0.12   | 1066.72±0.35 | 1176.43±0.17|
| P-12        | 1.09±0.05   | 1820.43±0.17 | 1272.73±0.06 | 23.4±0.23    | 67.08±0.05   | 2145.27±0.16 | 2457.55±0.29|
| R-1         | 2.55±0.29   | 1195.44±0.06 | 1156.92±0.26 | 4.2±0.12     | 73.57±0.29   | 1518.26±0.12 | 1689.99±0.40|
| R-2         | 1.25±0.06   | 1654.56±0.23 | 1145.67±0.12 | 16.8±0.35    | 12.16±0.09   | 2289.38±0.17 | 1789.35±0.20|
| R-4         | 1.34±0.12   | 1103.34±0.02 | 139.19±11.19 | 4.2±0.12     | 62.23±0.13   | 2275.22±0.13 | 2242.54±0.17|
| R-5         | 3.45±0.23   | 1872.23±0.13 | 1270.23±0.29 | 29.6±0.23    | 71.54±0.15   | 2275.22±0.13 | 2242.54±0.17|
| R-8         | 2.66±0.12   | 1886.23±0.06 | 1220.95±0.12 | 11.12±0.12   | 71.54±0.15   | 2275.22±0.13 | 2242.54±0.17|
| R-11        | 1.09±0.02   | 1985.54±0.17 | 1253.64±0.23 | 4.2±0.12     | 62.23±0.13   | 2275.22±0.13 | 2242.54±0.17|
| R-12        | 1.32±0.11   | 1945.12±0.07 | 1168.78±0.06 | 12.8±0.29    | 54.25±0.14   | 1290.69±0.29 | 1176.36±0.17|
| R-9         | 1.6±0.61    | 1875.34±0.29 | 1032.77±0.35 | 13.8±0.35    | 56.43±0.17   | 1290.69±0.29 | 1176.36±0.17|
| WB-379      | 4.3±0.12    | 1789.34±0.26 | 1224.46±0.17 | 11.4±0.12    | 34.5±0.13    | 1354.76±0.06 | 1612.86±0.06|
| WB-966      | 1.28±0.03   | 1888.78±0.29 | 1324.25±0.14 | 15.4±0.35    | 41.4±0.10    | 1958.45±0.23 | 2275.54±0.23|
| WB-115      | 2.19±0.67   | 1976.65±0.17 | 1245.91±0.29 | 17.2±0.12    | 57.38±0.17   | 2465.14±0.08 | 1747.5±0.29 |
Table 1: Continue

| Item   | Value       |
|--------|-------------|
| WB-1677| 1.07±0.02   |
| WB-195 | 1.35±0.02   |
| WB-1680| 1.21±0.06   |
| WB-1678| 1.35±0.03   |
| WB-54  | 2.31±0.01   |
| WB-969 | 2.09±0.05   |
| WB-6   | 3.33±0.19    |
| WB-1402| 1.09±0.01   |
| WB-257 | 1.28±0.03   |
| WB-1681| 3.67±0.06   |
| WB-185 | 2.22±0.01   |
| WB-1679| 1.18±0.02   |
| WB-371 | 1.15±0.03   |
| WB-22  | 1.34±0.02   |
| WB-1492| 1.34±0.03   |
| WB-1282| 2.23±0.02   |
| WB-216 | 1.26±0.09   |
| WB-877 | 1.26±0.10   |
| WB-341 | 1.28±0.05   |
| WB-222 | 1.25±0.03   |
| WB-1446| 1.09±0.05   |
| WB-335 | 2.22±0.12   |
| WB-1643| 1.31±0.03   |
| WB-83  | 2.12±0.02   |
| WB-1634| 1.15±0.09   |
| DE-4   | 1.15±0.02   |
| K-13   | 1.22±0.07   |
| K-16   | 1.34±0.02   |
| K-14   | 1.29±0.05   |
| K-20   | 2.54±0.29   |
| SR-1   | 1.33±0.11   |
| SR-2   | 2.69±0.27   |
| B-1    | 1.02±0.01   |
| B-10   | 1.34±0.12   |
| B-16   | 1.57±0.29   |
| B-17   | 1.06±0.09   |
| B-18   | 2.76±0.23   |
| B-20   | 1.09±0.04   |
| MT-5   | 1.06±0.01   |
| KS-1   | 1.33±0.02   |
| KS-10  | 2.12±0.07   |
| KS-11  | 2.27±0.03   |
| WB-1677| 1865.45±0.06 |
| WB-195 | 1987.45±0.23 |
| WB-1680| 1873.56±0.17 |
| WB-1678| 1789.23±0.13 |
| WB-54  | 1912.56±0.29 |
| WB-969 | 1932.57±0.06 |
| WB-6   | 1872.45±0.12 |
| WB-1402| 1100.04±0.24 |
| WB-257 | 1912.23±0.35 |
| WB-1681| 1953.44±0.12 |
| WB-185 | 1267.76±0.29 |
| WB-1679| 1765.92±0.20 |
| WB-371 | 1200.65±0.23 |
| WB-22  | 1847.59±0.17 |
| WB-1492| 1178.65±0.06 |
| WB-1282| 1923.78±0.17 |
| WB-216 | 1837.56±0.06 |
| WB-877 | 1008.65±0.17 |
| WB-341 | 1532.56±0.17 |
| WB-222 | 1977.78±0.35 |
| WB-1446| 1212.32±0.12 |
| WB-335 | 1954.17±0.10 |
| WB-1643| 1887.45±0.06 |
| WB-83  | 1711.45±0.23 |
| WB-1634| 1976.45±0.12 |
| DE-4   | 1785.29±0.40 |
| K-13   | 1675.34±0.17 |
| K-16   | 1754.58±0.29 |
| K-14   | 1176.54±0.06 |
| K-20   | 1267.45±0.17 |
| SR-1   | 1596.23±0.13 |
| SR-2   | 1921.12±0.07 |
| B-1    | 1856.57±0.17 |
| B-10   | 1945.56±0.12 |
| B-16   | 1898.58±0.23 |
| B-17   | 1976.45±0.03 |
| B-18   | 1989.97±0.29 |
| B-20   | 1100.23±0.12 |
| MT-5   | 1156.76±0.23 |
| KS-1   | 1156.78±0.12 |
| KS-10  | 1643.34±0.17 |
| KS-11  | 1587.45±0.06 |
**Table 1: Continue..........................**

| Location | Value 1 ± SE Value 2 |
|----------|----------------------|
| KD-5     | 1.36 ± 0.15          |
| KD-7     | 1.18 ± 0.02          |
| KD-11    | 1.29 ± 0.05          |
| KD-13    | 1.23 ± 0.29          |
| KD-16    | 2.6 ± 0.29           |
| KD-17    | 1.05 ± 0.29          |

| Arka Anoop | Value 1 ± SE Value 2 |
|------------|----------------------|
| UG-5       | 2.55 ± 0.06          |
| UG-6       | 1.55 ± 0.01          |
| UG-7       | 1.34 ± 0.17          |
| UG-9       | 2.77 ± 0.40          |
| UG-10      | 2.11 ± 0.06          |
| UG-11      | 1.33 ± 0.18          |
| UG-12      | 2.34 ± 0.06          |
| UG-13      | 1.11 ± 0.06          |
| SFB-1      | 1.3 ± 0.33           |
| N-1        | 2.87 ± 0.17          |
| N-4        | 2.23 ± 0.02          |
| N-10       | 1.22 ± 0.12          |
| N-13       | 2.64 ± 0.29          |
| N-15       | 2.09 ± 0.03          |
| MR-2       | 1.22 ± 0.21          |
| VLR        | 1.27 ± 0.02          |
| UJ         | 2.22 ± 0.13          |
| UD-1       | 3.72 ± 0.17          |
| UD-3       | 1.13 ± 0.01          |
| AVG        | 1.73 ± 0.05          |

| Value 1 ± SE Value 2 | 1923.45 ± 0.23 |
|----------------------|----------------|
| 1714.56 ± 0.17      |
| 1187.54 ± 0.23      |
| 1234.56 ± 0.12      |
| 1854.25 ± 0.12      |
| 1232.25 ± 0.21      |
| 1765.34 ± 0.10      |
| 1256.78 ± 0.17      |
| 1394.56 ± 0.29      |
| 1900.23 ± 0.06      |
| 1232.78 ± 0.12      |
| 1735.47 ± 0.12      |
| 1856.67 ± 0.17      |
| 1857.56 ± 0.29      |
| 1852.56 ± 0.16      |
| 1834.56 ± 0.17      |
| 1966.45 ± 0.17      |
| 1788.56 ± 0.12      |
| 1374.56 ± 0.29      |
| 1923.67 ± 0.06      |
| 1923.54 ± 0.17      |
| 1888.45 ± 0.26      |
| 1658.55 ± 0.06      |
| 1690.72 ± 0.17      |

| Value 2 | 1215.42 ± 0.17 |
|---------|----------------|
| 1246.39 ± 0.17 |
| 1250.67 ± 0.29 |
| 1231.39 ± 0.11 |
| 1150.24 ± 0.14 |
| 1232.52 ± 0.14 |
| 1230.32 ± 0.18 |
| 1225.03 ± 0.02 |
| 1318.89 ± 0.23 |
| 1125.73 ± 0.12 |
| 1225.38 ± 0.12 |
| 1275.38 ± 0.35 |
| 1157.14 ± 0.08 |
| 1130.22 ± 0.06 |
| 1324.25 ± 0.14 |
| 1324.67 ± 0.29 |
| 1263.01 ± 0.01 |
| 1322.68 ± 0.17 |
| 1345.95 ± 0.17 |
| 1272.73 ± 0.06 |
| 1246.26 ± 0.15 |
| 1223.53 ± 0.15 |

| Value 3 | 10.4 ± 0.12 |
|---------|-------------|
| 16.8 ± 0.12 |
| 13 ± 0.35 |
| 14.1 ± 0.06 |
| 14.6 ± 0.17 |
| 8.2 ± 0.12 |
| 28.2 ± 0.40 |
| 17.2 ± 0.12 |
| 19.8 ± 0.12 |
| 8.26 ± 0.06 |
| 12.4 ± 0.23 |
| 27.2 ± 0.12 |
| 14.2 ± 0.35 |
| 31.4 ± 0.06 |
| 10.72 ± 0.17 |
| 1 ± 0.23 |
| 12.48 ± 0.23 |
| 9.6 ± 0.29 |
| 9.8 ± 0.17 |
| 39.6 ± 0.12 |
| 14.6 ± 0.17 |
| 28 ± 0.29 |
| 18.2 ± 0.12 |
| 15.8 ± 0.23 |
| 15.75 ± 0.21 |

| Value 4 | 51.78 ± 0.40 |
|---------|--------------|
| 43.56 ± 0.29 |
| 29.4 ± 0.23 |
| 63.35 ± 0.20 |
| 72.33 ± 0.17 |
| 25.89 ± 0.23 |
| 45.51 ± 0.17 |
| 58.76 ± 0.63 |
| 61.5 ± 0.29 |
| 60.87 ± 0.29 |
| 47.1 ± 0.06 |
| 71.6 ± 0.17 |
| 77.85 ± 0.23 |
| 32.77 ± 0.12 |
| 45.04 ± 0.29 |
| 49.15 ± 0.09 |
| 45.62 ± 0.35 |
| 44.44 ± 0.25 |
| 93.34 ± 0.19 |
| 23.74 ± 0.06 |
| 68.39 ± 0.06 |
| 1153.38 ± 0.17 |
| 53.3 ± 0.18 |

| Value 5 | 2511.48 ± 0.28 |
|---------|-----------------|
| 2345.57 ± 0.12 |
| 2395.14 ± 0.08 |
| 1826.82 ± 0.23 |
| 1699.55 ± 0.17 |
| 1103.97 ± 0.06 |
| 1654.48 ± 0.23 |
| 2632.32 ± 0.18 |
| 2237.88 ± 0.23 |
| 1819.22 ± 0.14 |
| 1882.25 ± 0.12 |
| 1851.62 ± 0.23 |
| 1956.47 ± 0.06 |
| 1943.45 ± 0.26 |
| 2308.24 ± 0.29 |
| 1496.61 ± 0.29 |
| 1540.89 ± 0.15 |
| 1723.79 ± 0.06 |
| 1863.44 ± 0.12 |
| 1956.22 ± 0.13 |
| 1971.53 ± 0.29 |
| 2308.24 ± 0.29 |
| 1496.61 ± 0.29 |
| 1540.89 ± 0.15 |
| 1723.79 ± 0.06 |
| 1863.44 ± 0.12 |
| 1956.22 ± 0.13 |
| 1971.53 ± 0.29 |
| 1496.61 ± 0.29 |

| Value 6 | 9.6 ± 0.29 |
|---------|------------|
| 3.8 ± 0.15 |
| 4.2 ± 0.12 |
| 12.16 ± 0.16 |
| 1057.52 ± 0.08 |
| 1115.06 ± 0.54 |
| 363.3 ± 0.18 |
| 1.24 ± 0.17 |

*Mean±SE values with different superscripts between the genotypes within the same column are significantly different from each other. (ANOVA; DUNCAN post-hoc; P<0.05)
In a previous study, Beebe et al. (2000) have reported that the common bean contain, 3684, 2120, 1466, 10, 9 and 15 mg/kg (mean values) of P, S, Ca, B, Cu, and Mn respectively. According to Moraghan and Grafton, (2001), P, Mg and B contents of common bean ranged between 4500 to 5400, 1700 to 2300, 10.1 to 12.7 mg/kg, respectively. A study carried out by Mesquita et al. (2007), have indicated the P, S, Ca, Mg, Cu and Mn content ranged from 4500 to 7300, 300 to 2800, 1800 to 3400, 2800 to 4700, 11.37 to 17.73, 14.93 to 28.90, mg/kg, respectively. In yet another study, carried out by Mario et al. (2009) P, S, Ca, Mg, B, Cu, and Mn content were reported to range between 4000 to 5600, 2200 to 2800, 1000 to 2600, 1300 to 2875.44 mg kg⁻¹ (MR-2) with an average of 1765.87 mg kg⁻¹  and Magnesium content was found to range from 1057.52 mg kg⁻¹ (WB-371) to 2654.18 mg kg⁻¹ (K-16) with an average of 1860.14 mg kg⁻¹. Boron content of 84 genotypes ranges from 1 mg kg⁻¹ (WB-956) to 3.67 mg kg⁻¹ (UD-1) with an average of 1.73mg kg⁻¹. Wide variation ranging from 4.2 mg kg⁻¹ (R-4) to 62.8 mg kg⁻¹ (SR-1) with an average of 15.75 mg kg⁻¹ was found in copper content. Manganese content varies from 12.16mg kg⁻¹ (R-4) to 96.54 mg kg⁻¹ (UG-10) with an average of 53.53 mg kg⁻¹. Genotype WB-956 was found to have minimum boron and Sulphur content. Table 1 and represent the mean values of mineral contents observed in seeds of 84 diverse common bean genotypes.

In developing countries, people usually take cereal grains and legumes because of being cheap. But their intake does not satisfy the mineral requirements of these people. Guzman-Maldonado et al. (2000). In last decade, poor health, lower worker productivity, high rate of mortality and morbidity, increasing rates of chronic diseases (coronary
heart disease, cancer, stroke, and diabetes) and permanent impairment of cognitive abilities of infant born from micronutrient deficient mother were being found associated to poor micronutrient nutrition (Welch and Graham, 2000; Graham et al., 2001; Sanghvi et al., 2007). Earlier the micronutrients like, Fe, Zn, folate were discussed because of their concern with the public health Sanghvi et al. (2007). But nowadays, Se and B deficiency is also gaining importance for their inevitable role in human nutrition Graham et al. (2001). Besides, other beneficial effects of B; it improves the brains electrical activity, cognitive performance, and short-term memory for elders. It had demonstrated preventive and therapeutic effects in a number of cancers, such as prostate, cervical, and lung cancers, and multiple and non-Hodgkin’s lymphoma; and may help ameliorate the adverse effects of traditional chemotherapeutic agents (Pizzorno, 2015). On the other hand, Ca had also proven promising against osteoporosis, hypertension, and colon cancer Mario et al. (2009). In fact all the mineral elements are beneficial to health in one way or the other. So, the need of the hour is to develop such strategies which can improve the micronutrient quality and quantity of some staple food crops. One such strategy is to use bio fertilizers for instance, in a study carried out by Saikia et al., (2018), an increase in nitrogen and potassium content has been reported in a common bean cultivar after the application of consortium of biofertilizers. But biofertilizers mostly provide primary nutrients to the plants. So this strategy can be used to biofortify limited nutrients and to a certain extent beyond which the increase in bio fertilizers cannot lead to any improvement in mineral content. Therefore, a much potential strategy/ies is/are needed and plant breeding is explicitly one such practicable strategy. A plant breeding strategy, if successful, will not eliminate the need for supplementation, fortification, dietary diversification, and disease reduction programs in the future to combat micronutrient malnutrition. Nevertheless, this strategy does hold great promise for significantly reducing recurrent expenditures required for these higher-cost, short-run programs by significantly reducing the numbers of people requiring treatment.

**Correlation among micronutrient contents**: Positive and significant correlation was found between B & P (r=0.305, p<0.01), Ca & Mg (r=0.366, p<0.01), Ca & Cu (r=0.347, p<0.01), Mg & Cu (r=0.249, p<0.05) whereas positive but non-significant correlation was found between B and Mn, P and Mg, Mn and P, S and Ca, S and Mg, Mn and S and Cu and S. However, negative and significant correlation was found between B and Ca (r=−0.300, p<0.01) and negative but non-significant correlation was found between B and S/Mg/Cu, S and P, Ca and P/Mg, Cu and P/Mn, Mn and Mg (Table 2).

**CONCLUSION**

We evaluated common bean germplasm for various minerals – B, P, S, Cu, Mn, Mg and Ca and got wide variability in content of each mineral element analysed. The existence of genetic variability showed that selection was possible for the common bean germplasm with a high mineral content for diet enrichment (biofortification). Molecular characterisation followed by identification of genomic loci contributing for accumulation of these minerals through molecular breeding may lead to the production of fortified common bean with high mineral content. Biofortification in a crop like common bean, which is known as the ‘Poor Mans’ Meat’ can really help to address the problem of malnutrition in world, especially the poor countries wherein, common bean is used as a staple food. We also need to focus on the bioavailability of these biofortified minerals in gut. So that, the aim of dealing with the malnourished populations (trace element deficient) would be served.

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**REFERENCES**

Ahmad, W., Niaz, A., Kanwal, S., Rahmatullah, Rasheed, M.K. (2009). Role of boron in plant growth: a review. *J. Agric. Res.* **47**(3): 329-337.

Baker, D.H. (1986). Utilization of isomers and analogs of amino acids and other sulfur-containing compounds. *Progress in Food and Nutrition Science.* **10**: 133178.

| Table 2: Correlation among various elements. |
|---|---|---|---|---|---|---|---|
|   | B  | P   | S   | Ca  | Mg  | Mn  | Cu  |
| B | 1  |     |     |     |     |     |     |
| P | 0.305** | 1  |     |     |     |     |     |
| S | -0.093 | -0.019 | 1  |     |     |     |     |
| Ca | -0.300** | -0.199 | 0.022 | 0.366** | 1  |     |     |
| Mg | -0.177 | 0.023 | 0.018 | 0.347** | 0.249* | -0.014 | 1  |
| Mn | 0.067 | 0.094 | 0.091 | -0.19 | -0.084 | 1  |     |
| Cu | -0.027 | -0.035 | 0.073 | .347** | 0.249* | -0.014 | 1  |

**. Correlation is significant at the 0.05 level (2-tailed).**

**. Correlation is significant at the 0.01 level (2-tailed).**
Bass, J. K., and Chan, G. M. (2006). Calcium nutrition and metabolism during infancy. *Nutrition*. 22: 1057–1066.

Beebe, S., Gonzalez, V.A., Rengifo. (2000). Research on trace minerals in the common bean. *Food and Nutrition Bulletin*. 21 (4): 387-391.

Camara, C.R.S., Urrea, C.A., Schlege, V. (2013). Pinto Beans (*Phaseolus vulgaris* L.) as a functional food: Implications on human health. *Agriculture*. 3: 90-111.

Debouck, D.G., Toro, O., Paredes, O.M., Johnson, W.C., Gepts, P.(1993). Genetic diversity and ecological distribution of *Phaseolus vulgaris* (Fabaceae) in northwestern South America. *Economic Botany*. 47: 408–423.

Gaettle, L.M., and Chow, C.K. (2003). Copper toxicity, oxidative stress, and antioxidant nutrients. *Toxicology*. 189: 147–163.

Golub, E.E. (2011). Biominerallization and matrix vesicles in biology and pathology. *Seminars in Immunopathology*. 33: 409-417.

Graham, R.D., Welch, R.M., Bousi, H.E. (2001). Addressing micronutrient malnutrition through enhancing the nutritional quantity of staple foods: principles, perspectives and knowledge gaps. *Advances in Agronomy*. 70: 77-142.

Guzmán-Maldonado, S.H., Acosta-Gallegos, J., Paredes-López, O. (2000). Protein and mineral content of a novel collection of wild and weedy common bean (*Phaseolus vulgaris* L.). *Journal of Science of Food and Agriculture*. 80: 1874-1881.

House, W.A., Welch, R.S., Beebe, S., Cheng, Z. (2002). Potential for increasing the amounts of bioavailable zinc in dry beans (*Phaseolus vulgaris* L.) through plant breeding. *Journal of the Science of Food and Agriculture*. 82: 1452-1457.

Mario, P.C., Viviana, B.V., Juan, T.Y. (2009). Inorganic nutritional composition of common bean (*Phaseolus vulgaris* L.) Genotypes race chile. *Chilean Journal of Agricultural Research*. 69(4): 486-495.

Martínez, F., Uribe, A., Espinosa-García, M.T., Flores-Herrera, O., GarcíaPérez, C., Milán, R. (2002). Calcium modulates the ATP and ADP hydrolysis in human placental mitochondria. *International Journal of Biochemistry and Cell Biology*. 34: 992–1003.

Mc Connell, M., Mamidi, S., Lee, R., Chikara, S., Rossi, M., Papa, R., Mc Clean, P. (2010). Syntetic relationships among legumes revealed using a gene-based genetic linkage map of common bean (*Phaseolus vulgaris* L.). *Theoretical and Applied Genetics*. 121: 1103-1116.

Mesquita, F.R., Corrèa, A.D., Abreu, C.M.P., Lima, R.A.Z., Abreu, A.F. (2007). Linhagens de feijão (*Phaseolus vulgaris* L.): compo siçãoquímica e digestibilidadeprotéica. *Ciência e Agrotecnologia*. 31: 1114-1121.

Métayer, S., Seillez, I., Collin, A., Duchêne, S., Mercier, Y., Geraert, P.A., et al. (2008). Mechanisms through which sulfur amino acids control protein metabolism and oxidative status. *Journal of Nutrition and Biochemistry*. 19: 207-215.

Moraghan, J.T., and Grafton, K. (1997). Accumulation of calcium in bean cultivars differing in seed size. *Journal Science of Food Agriculture*. 74: 251-256.

Moraghan, J.T., and Grafton, K. (2001). Genetic diversity and mineral composition of common bean seed. *Journal of the Science of Food and Agriculture*. 81: 404-408.

Mousavi, S.R., Shahsavari, M., Rezaei. (2011). A general overview on manganese (mn) importance for crops production. *Australian Journal of Basic and Applied Sciences*. 5(9): 1799-1803.

Nordin, B. E. C. (1997). Calcium and osteoporosis. *Nutrition*. 13: 664–686.

Palma, M.N.N., Rocha, G.C., Valadares Filho, S.C., Detmann, E. (2015). Evaluation of acid digestion procedures to estimate mineral contents in materials from animal trials. *Asian Australas. Journal of Animal Sciences*. 28: 1624-1628.

Pizzorno L., (2015). Nothing Boring About Boron.

Palma, M.N.N., Rocha, G.C., Valadares Filho, S.C., Detmann, E. (2015). Evaluation of acid digestion procedures to estimate mineral contents in materials from animal trials. *Asian Australas. Journal of Animal Sciences*. 28: 1624-1628.

Pizzorno L., (2015). Nothing Boring About Boron.

Rizzoli, R., Boonen, S., Brandi, M. L., Burlet, N., Delmas, P., and Reginster, J. Y. (2008). The role of calcium and vitamin D in the management of osteoporosis. *Bone*. 42:246–249.

Saika, J., Saika, L., Phookan, D.B., and Nath, D. J. (2018). Effect of biofertilizer consortium on yield, quality and soil health of french bean (*Phaseolus vulgaris* L.). *Legume Research*. 41(5): 755-758.

Sanghvi, T., Ross, J., Heymann, H. 2007. Why is reducing vitamin and mineral deficiencies critical for development? *Food Nutrition Bulletin*. 28 (suppl.1): S167-S173.

Sathe, S.K., Deshpande, S.S., Salunkhe, D.K. (1984). Dry beans of *Phaseolus*: a review. Part 2. Chemical Composition: carbohydrates, fibre, minerals vitamins and lipids. *Food Sciences and Nutrition*. 21: 41-93.

Schmutz, J., Mc Clean, P., Mamidi, S., Wu, G.A., Cannon, S.B., Grimwood, J., Jenkins, J., Shu, S., et al (2014). A reference genome for common bean and genome-wide analysis of dual domestications. *Nature Genetcs*. 46: 707-713.

Talukder, Z.I., Anderson, E., Miklas, P.N., Blair, M.W., Osorno, J., Dilawari, M., Hossain, K.G. (2010). Genotypic diversity and selection of genotype to enhance Zn and Fe contents in common bean. *Canadian Journal of Plant Science*. 90: 49-60.

Welch, R.M., and Graham, R.D. (2000). A new paradigm for world agriculture: productive, sustainable, nutritious, healthful food systems. *Food and Nutrition Bulletin*. 21: 361-366.

http://soils.wisc.edu/facstaff/barak/soilscience326/listofsel.html20th Aug; 2018

http://www.oxfordfirst.com/royaume-uni/role-ca-ng-plante/animal.html, 15th Sep; 2018

http://www.wengflaustralia.com/_literature_71737/The_Importance_of_Sulphur, 22nd Sep; 2018

https://draxe.com/boron-uses/, 25th Aug; 2018

https://www.noble.org/news/publications/ag-news-and-views/2007/january/back-to-basics-the-roles-of-n-p-k-and-their-sources/, 20th Aug; 2018

https://www.sciencedirect.com/topics/medicine-and-dentistry/manganese, 15th Sep; 2018

https://ww1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex789, 20th Aug; 2018

http://www.fao.org/docrep/field/003/ab470e/ab470e06.html, 25th Aug; 2018