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**Sharad Kumar Markole**
Department of Agronomy, College of Agriculture, Hyderabad, Telangana, India

**K Suresh**
Associate Professor Department of Agronomy, College of Agriculture, Rajendranagar, Hyderabad, Telangana, India

**A Madhavi**
Principal Scientist & Head, AICRP on Weed Management, College of Agriculture Rajendranagar, Hyderabad, Telangana, India

**M Shanti**
Senior Scientist (SSAC) AICRP on Forage Crops, ARI, PJTSAU, Rajendranagar, Hyderabad, Telangana, India

**Corresponding Author:**
**Sharad Kumar Markole**
Department of Agronomy, College of Agriculture, Hyderabad, Telangana, India

# Agronomic biofortification and nutrient uptake of sorghum (*Sorghum biochor* L.) as influenced by fertilization strategies

**Sharad Kumar Markole, K Suresh, A Madhavi and M Shanti**

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## Abstract
The micronutrient required in minute quantity and their deficiency leads to diminished growth and yield of crops. The field experiment was carried out at College Farm, Rajendranagar during *rabi* 2015-16 with factorial randomized block design with two factors sorghum genotypes and zinc levels. Findings revealed that varieties and fertilization spray had significant on zinc concentration and uptake by grain and stover of sorghum. Variety CSV – 31 ($V_2$) and soil application of zinc sulphate @ 50 kg $ha^{-1}$ + foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering ($F_5$) gave significantly highest zinc concentration and uptake by grain and stover in comparison to their respective treatments.

**Keywords:** Micronutrient required, biofortification, *Sorghum biochor* L.

## Introduction
Most of the micronutrients are not only important for plants but also for animals and humans. World Health Organization (WHO 2002) [1] reported deficiencies of Zn, iron (Fe) and vitamin A in human population of developing countries. Human Zn deficiency is the fifth major cause of diseases and deaths in these countries (WHO, 2002) [1]. Around the world, 2.7 billion people are Zn deficient (Muller and Krawinkel, 2005, WHO, 2002) [2, 1]. About half of the world's population is under risk of Zn deficiency and prevalence is more in developing countries of Asia and Africa (Brown *et al.* 2001) [1], where cereal grains are staple food. Low levels of Zn and Fe in the cereal grain might be a risk factor for micronutrient malnutrition in the people who depend much on these cereals in their diets (Musa *et al*, 2012) [4]. Globally Zn is now recognized as the fifth major nutrient deficiency (Hotz and Brown, 2004) [5] after Protein-Calorie, Iron, Vitamin A and Iodine and according to the International Zinc Nutrition Consultation Group (IZiNCG) as much as one-third of the world's population may be at risk from inadequate Zn uptake. Zinc deficiency affects two billion people globally and more than 450,000 deaths annually in children under the age of 5 is due to zinc deficiency (Black *et al*, 2008) [6].

The required Zn intake depends on gender and growth stage. Generally, it is 10 mg Zn per day for adult women and 12 mg Zn per day for adult men. However, women during pregnancy and lactation require up to 14 mg Zn per day. These intake levels are generally not fulfilled in developing countries due to high reliance on cereal grains low in Zn for their daily calorie intake (ACC/SCN, 2004, Bouis and Welch, 2010). A diet of 330-400 g cereals per day supplies only 4-6 mg Zn per day in the case of rice and 8-18 mg Zn per day in the case of wheat. For a better Zn nutrition in human beings, cereal grains should contain around 40-60 mg Zn $kg^{-1}$ (Prasad *et al.,* 2012). Moreover, the population with severe Zn deficiency is eating cereal grains produced on Zn-deficient soils of India, Pakistan, China, Iran and Turkey (Alloway, 2008). Supplementation, food diversification/modification and food fortifications were previously recommended to solve Zn deficiency in humans. Biofortification is a recently devised approach to correct human Zn deficiency. It uses genetic and agronomic approaches to increase Zn bioavailability to humans (the amount of human absorbable Zn in food is termed as 'Zn bioavailability' in the dissertation) in edible parts of plants.

Sorghum is the most important food and fodder crop of dry land agriculture. It is one among the few resilient crops that can adapt well to future climate change conditions, particularly drought, soil salinity and high temperatures. The crop is drought and heat tolerant, and is especially important in arid and semi-arid regions due to its short duration, fast growing nature, and high biomass producing character where, the grain is the staple food for poor and rural people.

The productivity of sorghum is low due to growing of this crop on marginal lands and continuous use of macronutrients. Zinc has emerged as the most widespread micronutrient deficiency in soils and crops worldwide, resulting in severe yield losses and deterioration in nutritional quality (Sillanpaa, 1982) [9]. Plant breeding strategy (genetic bio-fortification) appears to be a suitable and cost-effective approach useful in improving Zn concentration in grain. However it is a long term process requiring sustainable effort and resources. It is therefore essential for short term approach to improve Zn concentration in cereal grains. Application of Zn fertilizers as Zn enriched N, P, and K fertilizers (e.g. agronomic biofortification) to soil and /or foliage seems to be a practical approach to improve zinc concentration in grains. Zinc Sulphate ($ZnSO_4$) is the widely applied source of Zn because of its high solubility and low cost. Combined application of soil and foliar Zn fertilizers is the most effective way to maximize grain Zn accumulation (Cakmak *et al.* 1996) [10]. Agronomic biofortification strategy appears to be essential in keeping sufficient amount of available Zn in soil solution and maintain adequate Zn transport to grain during the reproductive stage. Agronomic biofortification of food crops might be an effective tool in combating micronutrient malnutrition in human population (Cakmak, 2008) [11].

## Materials and Methods

The research work was conducted at during *rabi* 2015-16 at College Farm, College of Agriculture, Rajendranagar, Hyderabad. The farm is geographically situated at an altitude of 542.6 m above mean sea level at 18.50º N latitude and 77.53º E longitude and falls under Southern Telangana agro-climate zone of Telangana, to find out optimum dose of zinc and evaluate the response of sorghum genotypes to zinc fertilizer on growth, yield attributes and yield of sorghum genotypes. Site of experiment was sandy loam in texture having neutral in reaction (7.94), low in organic carbon (0.31), available nitrogen (256 kg. $ha^{-1}$), medium in available phosphorus (20.4 kg. $ha^{-1}$) and potassium (241 kg. $ha^{-1}$) and low in zinc available (0.62 ppm).

The experiment was carried out with two genotypes of sorghum ($V_1$: CSV-15 and $V_2$: CSV-31) as first factor and six zinc levels $F_1$: Control (No zinc), $F_2$: soil application of zinc sulphate @ 25 kg $ha^{-1}$, $F_3$: soil application of sulphate @ 50 kg $ha^{-1}$, $F_4$: soil application of zinc sulphate @ 25 kg $ha^{-1}$ + foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering, $F_5$: soil application of zinc sulphate @ 50 kg $ha^{-1}$ + foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering, $F_6$: foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering as second factor. Total twelve treatment combinations were laid out in randomized block design with factorial concept and replicated thrice.

The furrow was opened manually in each plot at a distance 45 cm. Before sowing the seed, half dose of nitrogen and full dose of zinc fertilizer according to calculated quantities as per treatment was applied in the opened furrow at a depth of about 8-10 cm. The nutrient N and Zn were applied in the form of urea and zinc sulphate, respectively. The recommended dose of phosphorus (40 kg $P_2O_5$ $ha^{-1}$) in the form of Diammonium phosphate was applied before sowing in all the plots. The fertilizers were covered with a 4-5 cm layer of soil. The remaining half dose of nitrogen in the form of urea was applied at 35 DAS as per treatment. In the previously opened furrows, seed were sown manually and covered with a thin layer of soil. The irrigations were given as and when required. The experimental field was kept weed free through one inter cultivating by hand hoe and hand weeding. The treatments were evaluated grain zinc content and zinc uptake of sorghum.

## Results and Discussion

### Zinc concentration and uptake by stover

Zinc concentration and uptake increased with different genotypes of sorghum, CSV-31 recorded higher stover zinc concentration and uptake (19.00 ppm 103.67 kg $ha^{-1}$ respectively) over CSV-15 (17.16 ppm and 98.34 kg $ha^{-1}$). Significant higher stover zinc concentration and uptake was recorded in $F_5$ treatment zinc sulphate @ 50 kg $ha^{-1}$ by foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering, (21.95 ppm and 120.62 kg $ha^{-1}$ respectively) over rest of the treatment and was followed by $F_3$, $F_2$, $F_6$ and $F_1$. Which was on par with $F_4$ (soil application of zinc sulphate @ 25 kg $ha^{-1}$+ foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering). The formation of NADPH or NADH is depending upon the Zn concentration and which might have involved in tapping and converting the radiation energy for photosynthetic activities and increased formation of sugars and starch. This result is in accordance with the results of Kene and Deshpande (1980) [12]. Similarly Phattarakul *et al.* (2012) [13] suggested that promoting the Zn content in vegetative tissues by foliar Zn application results in Zn being available for re-translocation into seeds. One of the reasons for the stimulated transport of Zn into seeds after the flowering stage might be related to significant increases in protein biosynthesis during the early stage of seed formation (Martre *et al.* 2003, Ozturk *et al.* 2006) [14, 15].

### Zinc concentration and zinc uptake by grain

Zinc concentration and uptake increased by grain with different genotypes of sorghum and zinc levels. Among the genotypes CSV-31 had recorded significantly more Zn concentration (ppm) and uptake (28.95 ppm and 82.95 kg $ha^{-1}$) by CSV-15. The highest zinc content and uptake in harvested seed was recovered in soil application of zinc sulphate @ 50 kg $ha^{-1}$ fallowed by foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering ($F_5$) which was on par with $F_4$ had significantly superior over rest of the treatments. Though the interaction effects of zinc levels and genotype for Zn content in grains was significant. It may be concluded that the sorghum cultivars vary in grain Zn content. These zinc concentrations in grain could be increased by genotype and application of zinc fertilizers. Improved grain Zn concentration in rice with application of Zn-coated urea fertilizer was also reported by Shivay *et al*. (2008) [16]. Wei *et al.* (2012) [17] reported increased grain Iron concentration and bioavailability in rice with foliar application of $FeSO_4$ and addition of $ZnSO_4$ to foliar Fe application increased both Fe and Zn content without altering Fe content and bioavailability. This may be due to the improvement of enzymatic function and the metabolic function of plant which increased the plant uptake. The similar results were obtained by Yadi *et al.*, (2012) [18] and Impa *et al.*, (2013) [19].

Cakmak *et al* (2010) [20] showed similarly that increasing pool of Zn in the vegetative tissue during the reproductive stage by spraying represents an important field practice in maximizing accumulation of Zn in grain. Zhang *et al* (2012) [22, 23] reported that foliar Zn application significantly increased the Zn concentration and the predicted bioavailability in both whole grain and flour of wheat. Cakmak (2008) [11] announced that foliar Zn application alone or in combination with soil Zn application significantly increased the Zn concentration in wheat grain.

Zn application up to three times compared with no Zn application (Yilmaz *et al.* 1997, Cakmak *et al.* 2010 [21, 20], Karim *et al.* 2012) [22, 23]. Foliar Zn applied is easily absorbed and transported through phloem as shown in wheat by using radio labeled Zn especially in plants grown under low Zn supply (Haslett *et al*., 2001, Erenoglu *et al.*, 2002) [24, 25]. Al though xylem transport of Zn has been indicated to be more important for Zn accumulation in rice grain than re-translocation of Zn from the leaves (Palmgren *et al.*, 2008) [26].

**Table 1:** Stover and Grain zinc content and zinc uptake of sorghum genotypes is affected by different zinc levels.

| Treatments | Stover | | Grain | | Crude protein (%) in grain |
|---|---|---|---|---|---|
| | Zn conc. | Zn uptake | Zn conc. | Zn uptake | |
| $V_1$CSV-15 | 17.16 | 98.34 | 6.49 | 68.30 | 6.49 |
| $V_2$ CSV-31 | 19.00 | 103.67 | 6.97 | 73.90 | 6.97 |
| SE(m) | 0.44 | 0.92 | 0.02 | 0.60 | 0.02 |
| C.D.(P=0.05) | 0.91 | 1.91 | 0.04 | 1.26 | 0.04 |
| $F_1$: Control (No zinc) | 13.89 | 64.73 | 22.39 | 50.73 | 5.70 |
| $F_2$: Soil application of zinc sulphate @ 25 kg $ha^{-1}$ | 17.59 | 101.70 | 25.87 | 73.41 | 6.35 |
| $F_3$: Soil application of zinc sulphate @ 50 kg $ha^{-1}$ | 18.41 | 104.68 | 26.18 | 76.38 | 6.51 |
| $F_4$: Soil application of zinc sulphate @ 25 kg $ha^{-1}$+ foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering | 20.56 | 118.56 | 28.72 | 81.02 | 7.77 |
| $F_5$: Soil application of zinc sulphate @ 50 kg $ha^{-1}$+ foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering | 21.95 | 120.62 | 28.95 | 82.95 | 8.09 |
| $F_6$: Foliar spray of $ZnSO_4$ @ 0.2% at knee high stage and at flowering | 16.10 | 95.78 | 24.26 | 62.10 | 6.18 |
| SE(m) | 0.75 | 1.59 | 0.16 | 1.04 | 0.03 |
| C.D.(P=0.05) | 1.58 | 3.31 | 0.34 | 2.18 | 0.07 |

## Conclusion
The finding revealed that variety CSV – 31 with soil application of zinc sulphate @ 50 kg ha-1 + foliar spray of ZnSO4 @ 0.2% at knee high stage and at flowering (F5) registered significantly maximum zinc concentration (grain and stover) and uptake by grain and stover as compared to other treatments.

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