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Methods to Enhance Selenium in Wheat through Biofortification: A Review

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Abstract

The micronutrient selenium (Se) is an important trace and building block element for humans as well as for other mammals. It is ubiquitous in soil but its supply to plants is limited due to its insoluble form high-iron, low-pH and leached soil. Thus, it leads limited supply of micronutrients from plant to animal and then to human consumer and in low concentration in regard to standard health requirements. Such type of flow causes deficiency of Se and enhances different types of diseases threats such as; cancer, heart diseases, many inflammatory conditions, thyroid dysfunction. Billion individuals are affected by Se deficiency worldwide. It demands the question of discovery different types of strategies to enhance the Se intake. The most common cereal crop is wheat which is used as staple food in many countries. The major cause of Se deficiency is Intake of low-Se based wheat. Enhancement of Se in wheat through biofortification methods seems a good strategies for enhancement of Se in wheat and overcome the Se deficiency in plants and ultimately in human and other mammals. In this study, we reviewed different strategies that can be used to improve the Se contents in wheat through biofortification.

Keywords: Biofortification; Wheat biofortification; Micronutrient

Introduction

Selenium is an important trace mineral and element of Mammalian. Although, body require this trace element in small amount but is a basic constituent of diet [1] i.e. it must be taken up by the body from the food it gets. It has great importance in human survival as it is involved in important biochemical processes going on in a body. It plays an important role in structural component of Selenoprotiens and enzymatic for the production of active thyroid hormone, which acts as an antioxidant and catalyst. It acts as a counteracting agent against the development of virulence and inhibits the growth of HIV [2-5]. Different research has indicated that it is important and key nutrient required by immune system. It also helps in sperm movement and decrease the probability of miscarriages. Selenium also helps in production of special proteins called antioxidant enzyme [6], which restricted cell damaging and protect the body after vaccination, like already mentioned it is required by the immune system. Some of the research shows its importance in preventing cancer and cardiovascular disease but no evidence has come so far. Moreover it protects the body against the toxic effects of the heavy metal or harmful substances.

Deficiency of Se

Deficiency of Se can cause severe and adverse effects on the body. Relationship between selenium deficiency and cardiovascular disease risk is still undiscovered but in other cases elevate level of Se lead oxidative stress and inflammation. The intake of selenium rich food required by the body reduces the level of cancer causing. These are being tested on large clinical trials which are held for the verification of research of research results [4].

There are different factors that cause Selenium deficiency and one of the most important is intake of food low concentration of selenium mineral, or long term feeding on vein can also cause Se deficiency. Se deficiency can also lead Keshan Disease in which abnormal heart muscles develop and it was the major reason of China children death. As a mineral source it also cause another disease named as Kashin-Beck Disease which is a joint and bone disease [7]. Myxedematous Endemic Cretinisim, cause intellectual disability. When body fails to absorb selenium gastrointestinal disorders occur which ultimate lead to Crohn's Disease. Selenosis is malnutrition of selenium in the blood which causes hair loss, nail deforming, mild nerve damage etc.

Source of Se

Plants grown in rich selenium soil are the best source of selenium diet. It all depends on the type of soil where the plantation was carried that how much selenium concentration is present in the soil is to be obtained. Food like fish, shellfish, red meat, serials, grains, and livestock can be good source of selenium. Brewer's Yeast and wheat are always a healthy source of selenium diet. Below is a table showing the Se content in northeast and southwest region of China (Table 1).

Selenium in the environment

Selenium metal is present in environment across the world. Its concentration changes from land to land ranging from 0.1 -2.0 mg/

Crop	Northeast	Southwest
	nmol/g	nmol/g
Rice	0.30 ± 0.029	0.09 ± 0.005
Wheat	0.07 ± 0.005	0.06 ± 0.006
Millet	0.06 ± 0.006	-
Corn	0.04 ± 0.002	0.08 ± 0.004

Table 1: Selenium content of cereals produced from endemic areas in Northeast (Heilongjiang Province) and Southwest (Sichuan and Yunnan Provinces) China*.

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kg while in seleniferous areas can go up to 10 mg/kg [8]. Now a day biologists take more interest in micronutrients as it has found to be a vital micronutrient and is significant for many of the organisms including humans, animals and higher plants [9-11]. Selenium deficiency and toxicity both are of great importance for humans and animals, as it can be lethal in some cases of Keshan's Disease.

How plants take up selenium?

Selenium is present as a predominant state Selenate in well oxidized and alkaline soil while in more acidic and well drained soils this is present as selenite [12]. As a result of Selenite and sulfate similar chemical properties, Selenite is taken up by the sulfate transporters [13]. The picking up of selenite by the plants depends upon the health, nutrition factors and external concentration of both the sulfate and selenate. Higher the sulfate content more will be the selenate uptake and vice versa [14]. But this condition may change from plant to plant and even transport system. There are plants which very Se accumulation in plants differs from between species or even within the species. Accumulation of Se in high amount is known as hyper accumulation. Statistics reveal that this can vary from 1000-10,000 µg/kg dry weight where as other accumulates it like <20 mg/kg. Se accumulation not depend only structure and seasonal changes of plant but also depends on its movement from shoot to root during fall and from older to younger leaves and reproductive organs in summers [15]. Furthermore Se hyper-accumulator or non-accumulator doesn't illustrate any considerable difference when grown in the same field. As far as these crop plants are concerned a variety of differences in the accumulation of Se have been reported. Any significant amount of Se concentration has not shown in wild wheat or wheat landraces grain while diploid wheat grains do [11]. In plants bioavailability of Se may be a factor which controls the movement of Se uptake [16]. Genotypic variation might become prominent if there is high Se concentration. The research on 14 hard red winter wheat species discovered this hypothesis, and the environmental factors can also be the restrictive factors [17]. This has been recognized so frequently that inter or intra specie deviations for Se accumulation exists but fact is that genetics of Se accumulation have hardly ever been investigated. However recombinant interbred has shown the genetic basis of selenate tolerance A. thaliana which reveals 3 QTLs (quantitative trait loci) on chromosome no. 1, 3 and 5. This can elucidate about the 24% of the variation with reference to the tolerance index defined by root-length inhibition and 32% of the root length in terms of the phenotypic deviation [18].

To overcome Se scarcity the farmers use algorithmic bio-fortification which is the addition of bioavailable Se in fertilizers. This also has been experienced different types of crops and in many countries [19-22]. As for as inter and intra-specific variation is concerned these can be explored and then bio-fortified (genetic bio-fortification) [23]. Scientists and farmers are trying to enhance Se quantity in crop by adding Se fertilizers to overcome the world problem of fighting against Se deficiency. To put selenium into the soil is a cheap and of low cost method which can be taken up by plants and so the humans later. The costs for mechanically adding the Se to soil is about US$1.00/ha. It was demonstrated by the high level blood Se in the Finland post 1983. Experimentation also shows the high bioavailability of Se to wheat Se fertilized is as compare to American wheat, was naturally high in Se concentration. The trialing in Finland also illustrate the considerable result of Se uptake by wheat by soil application or foliar which were elevate from 0.1 mg/kg to 0.25 mg/kg. Now Se in range of 5-10 g/ha is applied which is safe and is readily absorbed. Se fertilization has been accomplished for over 30 years but no Se build-up has occurred, and positive response continues to be attaining from Se application [24].

It has been proved by many scientists that selenate is much more effective as compare to selenite when these are applied directly to soil or as foliar in fertilizers [25-30]. For example, when selenate applied to the soil in 10 g/ha the hardly illustrates grain content of 100 µg/kg, but to attain this much of grain content with the selenite 110 g/ha was to be applied [27]. Furthermore a study demonstrated the elevate level of selenate over the sandy clay formed considerably enhanced results on grain content in barely by increasing the amount from 33 µg/kg to 234 µg/kg, whereas selenite didn't demonstrate any change [29]. It might be due to the property of selenite colliding with soil and become limiting factor for plants. Some parameters should be taken under consideration which is the application of Se form e.g the time of foliar application and the characteristic of soil. The major cause of UK low Se diet is wheat low in Se residues. A study was performed to increase the high yield of UK wheat crop by using fertilizers. In this experiment two methods were used: one was the adding of selenate with sodium as a solution while the other was as granular Se-containing products. This explained that grain content were increased by 16–26 ng Se g/ha fresh weight (FW) applied this conclude that 10 g/ha Se addition may raise the 10-fold of the Se concentration in the UK wheat and confirmed that the agronomic biofortification of wheat is reasonable. In addition it showed the increase of 20-35% in total recovery (grain and straw).

A study was also conducted on Maize to check against the uptake of Se. in this experiment three types of Se fertilizers were used which were liquid drench of Na2SeO4 (aq) (0–100 g Se ha^{-1}), a compound NPK + Se fertilizer (0–6 g Se ha^{-1}), or Se-enriched calcium ammonium nitrate (CAN + Se; 0–20 g Se ha^{-1}). At the end result was same for all of the forms of fertilizer plus the application rate. Mean of experimental values were taken and showed 20, 21 and 15 µg Se/kg for each gram of Se applied as Na2SeO4(aq), NPK + Se and CAN + Se, correspondingly. This can initiate the Se intake by human population by 26–37 µg Se person/d by adding 5g of Se/ha according to the pattern developed by national maize consumption in Malawi predominantly [31].

In South Australia the research done on wheat demonstrated progressive uptake of Se by the wheat crop when introduce to soil directly or by foliar application. The increase Se concentration was observed by 20- to 133-fold for soil and foliar by 6- to 20-fold, the maximum of which grain Se concentration of 12 mg kg^{-1} was obtained. When 4-120 g of Se/ha was applied there wasn't any effect on grain yield or protein content. Se with Na solution is an inexpensive and more reliable fertilization method which maintains Se level in body decrease the risk of developing cancer [11].

Brassica species is an efficient way for accumulation of Se and it can be used for the biortification of Se to fulfill the deficiency and gap in the food chain. To confirm this a study was carried out in the species of Brassica i.e. *B. rapa* and *B. napus* in field experiment which were applied by 0, 6 or 20 mg Se ha^{-1} as Na_2SeO_4 and foliar sprays of 30 mgSe/ha as Na_2SeO_4 or Na_2SeO_4. The results were Se concentration (1.89 µg/g) and (1.34 µg/g) after oil extraction fraction. It concludes that foliar spray is more effective and efficient. Studies exposed that 68-75% of Se was present in a useful content which is selenomethionine (SeMet). Brassica plants at rosette stage had taken up 30-40%, but the translocation to seeds was low. The experiment illustrated that agronomic bio-fortification of Brassica can also help in decrease the deficiency of Se.

Brazil lacks information on Se in agricultural crops. Though there is sign that low levels of Se are consumed by the population. The research was carried out under greenhouse conditions and have pots containing 3l of nutritive solution in a completely randomized factorial design, with seven Se concentrations : 0, 2, 4, 8, 16, 32, and 64 µmol/l and two forms of Se : sodium selenite-Na_2SeO_4 and sodium selenite – Na_2Se_4, with six replicates. The application of Se as selenate at low concentrations is more appropriate for lettuce bio-fortification because it helps in shoot biomass growth and level of Se in the shoot biomass. In both forms Se had two effects on lettuce plant metabolism: it acted as an antioxidant at low concentration and improved plant growth while on other hand at higher levels it reduced yield [6].

Conclusion

It is evident that wheat biofortified with Se is a safe and bioavailable source of organic Se and is recommendable for human consumption. Furthermore, biofortifcation appears to be preferable to process fortification with regard to prevention of Se-met oxidation during high temperature processing of wheat into puffed wheat biscuits. In conclusion biofortified wheat is a suitable food for improving selenium status in humans. However, further research is needed to verify its bioefficacy in selenium-deficient populations.

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