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Comparison of Selenium Accumulation in Edible Parts of Wheat and Broad Bean

Keman Bao [1,2,†], Yurong Wang [1,†], Xiaoping Du [2], Hada Wuriyanghan [3], Xu Wang [4], Jiatao Xie [1], Xiaohu Zhao [1,*] and Wei Jia [5]

1 National Key Laboratory of Agricultural Microbiology, College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China; bkm@webmail.hzau.edu.cn (K.B.)
2 Key Laboratory of Se-Enriched Products Development and Quality Control, Ministry of Agriculture and Rural Affairs/National-Local Joint Engineering Laboratory of Se-Enriched Food Development, Ankang 725000, China
3 Key Laboratory of Forage and Endemic Crop Biology (Inner Mongolia University), Ministry of Education, Hohhot 010020, China
4 Institute of Quality Standard and Monitoring Technology for Agro-Products of Guangdong Academy of Agricultural Sciences, Guangzhou 510640, China
5 College of Tobacco Science, Henan Agricultural University, Zhengzhou 450046, China
* Correspondence: xhzhao@mail.hzau.edu.cn
† These authors contributed equally to this work.

Abstract: The concentration of selenium (Se) in agricultural products primarily depends on the concentration of Se in soil and the ability of plants to accumulate Se. Selenium deficiency not only leads to decreased body resistance, but also increases the risk of cancer. The form and concentration of bioavailable Se is important for diet. The present study was carried out via field experiment with wheat and broad beans in soil of different Se concentrations (0, 1.12, and 11.2 kg·ha^{-1}), which was determined based on the national standard and the team's previous experience. Results indicated that the concentration of Se in the edible organs of wheat was higher than in broad bean, while the enriched Se concentration in the root of broad bean was more than twice and three times higher than that of wheat at medium and high levels of Se, respectively. Selenomethionine, which accounted for over half of the total Se speciations, was the dominant species in the edible parts of the two crops, followed by Selenocystine and methylselenocysteine. Through the analysis of the rhizosphere soil, it was found that Fe-Mn oxide-bound Se exceeded 80% of the total Se. Additionally, there was a significant linear correlation between the Se content in the edible parts of the two crops and the Se content in the soil. Findings suggested that wheat was more favorable than broad beans as Se supplement crops in a Se-supplied field.

Keywords: wheat; broad bean; distribution; speciation; selenium uptake; soil

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1. Introduction

Selenium (Se) is widely recognized as an essential dietary trace element for both animals and humans, playing an important role in preventing various diseases and promoting health [1–3]. Deficiency in Se is a common hazard to humans, affecting more than half of the population all over the world [4–6]. Deficiency in Se often causes symptoms such as fatigue, decreased resistance and inflammatory diseases [6]. A daily diet has become a potential way for Se intake, and consumption of Se-enriched food products can increase the intake of Se. However, in most crops, the level of Se is still too low to meet the daily requirement. Deng et al. [7] singles out the utility of Se fertilization to increase Se concentration in crops, which is considered as an effective way of preventing dietary Se deficiency. Therefore, Se biofortification of food crops has been implemented in Se-deficient regions through applying Se fertilizer to soil, and with satisfactory results [8–11].

In addition to the total Se concentration in crops, Se speciation in plants is also an indispensable factor. Research has shown that the bioavailability and speciation of Se in dietary food are considered important factors owing to their diverse health benefits [12,13]. More bioavailability has been discovered in organic Se than in inorganic Se species for human beings [14,15]. Selenocystine (SeCys), selenomethionine (SeMet) and methylselenocysteine (MeSeCys), the dominant types of organic Se, exhibit unique effects of killing cancer cells and prophylactic efficacy [16,17].

Studies have pointed out that Se content and speciation in plants depend not only on Se concentration and its form in the soil, but also on the ability of plants to transport Se from soil, due to the differences in Se absorption efficiency among different plant species [18–20]. Accordingly, it is necessary to understand Se fractions in soil, the transfer patterns of Se from soil to plants and the characteristics of Se accumulation, distribution and translocation in different crop species. Therefore, at present, the comparative study of the main soil Se species under different Se concentrations of different crops in the same farmland has special significance for crop research and food development.

Wheat and broad beans are the staple crops in the world, playing crucial roles in replenishing Se supplies for inhabitants in areas with low Se-concentrated soil [21–23]. Food products made from wheat and broad beans, which could be a major source of Se intake, are deeply loved by people all over the world. Wheat, which is a highly important wheat crops, presented prominent efficiency in Se adsorption with a Se dose of 5 $g \cdot ha^{-1}$ [24]. Broad bean, established as one of the world's most crucial legume crops, also showed the ability to absorb and enrich Se [25]. However, from the literature review, there seems to be a lack of investigations on Se distribution and translocation in each organ of wheat and broad beans, especially when it comes to the comparison of these two crops. Moreover, the distinction of Se species between the two types of crops, and the concentration of organic Se in particular, remains unclear. Therefore, it is an experimental priority to explore the differences in the features of Se accumulation, distribution and speciation between wheat and broad beans in response to soil Se.

In the present study, the objective we undertook was to explore the differences in Se accumulation and speciation between two species of crops: wheat (cereals, monocotyledon) and broad bean (legumes, dicotyledonous) grown in soil with several Se concentrations. The concentrations of different Se speciations (soluble Se, Fe/Mn oxide-bound Se, exchangeable Se, organic-matter-bound Se, and residual Se) in the soil were also determined. This study attempted to provide insight into the characteristics of Se accumulation in wheat and broad beans, as well as the distribution and speciation of Se in edible crop organs.

2. Materials and Methods

2.1. Field Location and Experimental Design

Research on wheat (Zhengmai 9023) and broad beans (Lvbao) was carried out in the experimental field of the Micro-Element Research Center of Huazhong Agricultural University in Wuhan, Hubei province, China (30°21′ N, 114°10′ E) in September. Analyses were conducted on soil with pH 7.49, 11.32 $g \cdot kg^{-1}$ organic matter, 35.67 $mg \cdot kg^{-1}$ alkali-hydrolysable nitrogen, 89.49 $mg \cdot kg^{-1}$ Olsen-P, 233.60 $mg \cdot kg^{-1}$ available K and 0.26 $mg \cdot kg^{-1}$ total Se. The soil type is Alisols. The field was divided into three parts named as SeL, SeM and SeH, and Se fertilizer at three concentrations (0, 1.12 and 11.2 $kg \cdot ha^{-1}$, equivalent to Se) in the form of Na_2SeO_3 were applied to the soil, respectively. The Se concentration was determined based on the national standard (>3.0 $mg \cdot kg^{-1}$ is considered Se-poisoned soil) and the team's previous experience in several crops, and it was below the toxic concentration range. After the topsoil was sufficiently stirred, it was aged for 40 days under natural conditions to establish a field test system of different Se levels in the soil. After around 40 days, the soil became semi-moist and evenly mixed, arranged in a randomized complete block design; each treatment plot covered a 4.0 m^2 surface area (2.0 m × 2.0 m). This procedure was repeated four times. After ploughing at 20–25 cm depth and fertilizing with fertilizer 220 $kg \cdot ha^{-1}$ ($N{:}P_2O_5{:}K_2O$ = 17:17:17), broad beans and wheat were planted separately so that they would not interfere with each other. Normal water and fertilizer management and pest control were carried out in the growth stage of the plants, and the plants were no longer supplemented with fertilizer.

2.2. Samples Collection and Preparation

Soil samples and various plant organ samples were collected randomly in late May of the following year. Broad beans were harvested at the ripe stage, while the wheat was harvested after physiological maturation of the grains. A five-point sampling method was used for sampling in the fields with different Se concentrations, and 5 to 6 plants were taken from each group of fields. Soil samples were consistent with plant samples. After the collected plant samples were brought back to the laboratory, they were divided into leaves, stems, seeds, roots and so on for further processing. Then, the soil samples were collected from each plot (0–20 cm deep), air-dried, grounded and then sieved through a 100-mesh nylon cloth for analysis of Se concentration. Plant samples including roots, stems, leaves and seeds were washed 3 times with deionized water to remove dust [26]. After being air-dried at room temperature, all the samples were dried at 105 °C for 30 min, and then at 60 °C until the weight remained constant.

2.3. Determination of the Total Concentration Se in Plant and Soil

The total concentration of Se in plant samples was determined through adding HNO_3-$HClO_4$ (4:1) for digestion [26]. Then, Se concentration was measured with hydride-generation using an atomic fluorescence spectrometer (HG-AFS-8220, Beijing Titan Instruments Co., Beijing, China). For soil Se determination, the procedure was the same as the plant Se measurement, except that HNO_3-$HClO_4$ (3:2) was used for digestion. Soil samples were analyzed for Se fractions using the five-steps sequential extraction method described by Wang et al. and Liu et al. [26,27], with slight modification. After the above steps, extracts of various forms of Se (soluble Se, Fe/Mn oxide-bound Se, exchangeable Se, organic matter-bound Se, and residual Se) in the soil samples were obtained to prepare for the next analysis. For analytical quality control, analyses were certified using the GBW07403 (GSS-3) (yellow brown soil) standard (Sigma-Aldrich, St. Louis, MI, USA) and GBW10015 (GSB-6) (spinach). Blank and certified reference samples were analyzed along with the digestion of every batch, which presented a minimum of 89.27% (n = 4, SE = 0.045) and 94.31% (n = 4, SE = 0.024) recovery.

2.4. Enzymatic Hydrolysis for Se Speciation in Edible Tissues

Se speciation in the edible tissues of wheat and broad bean was determined according to the method of Sun et al. [28], with slight modification. Samples with a mass of 0.15 g were incubated in 5 mL 30 mM Tris-HCl buffer solution (pH 7.5) containing 15 mg protease K and 10 mg lipase VII for 24 h, in a dark 37 °C water bath. During enzymatic hydrolysis, a rotary shaker at 60 rpm was used to make sample slurries constantly and gently homogenized. Then, the hydrolyzed samples were centrifuged at 3000 rpm for 30 min. Finally, the supernatants were filtered through a 5000-Da molecular filter and stored at −20 °C for Se speciation determination.

2.5. Determination of Se Speciation in Edible Tissues via HPLC-ICP-MS

High-performance liquid chromatography (HPLC, Agilent Technologies 1260 series) coupled with inductively coupled plasma mass spectrometry (ICP-MS, 7700X, Agilent Technologies, Hong Kong) was used for measuring Se speciation. Chromatographic separations including a pre-column and a Hamilton PRP X-100 anion exchange column (10 μm, 4.1 mm × 250 mm). The mobile phase was 5 mM of ammonium citrate containing 2% methanol at pH 4.3. The peak area of the chromatographic signal was measured and quantified through monitoring the isotope 78 Se. The retention time was determined using a mixed consisting of comprising standards containing 50 $\mu g \cdot L^{-1}$ MeSeCys, SeCys, SeMet, selenite and selenate. For analytical quality control, it presented 90.04% recovery.

2.6. Statistical Analysis of Data

All data were statistically analyzed using SPSS 20.0 software. Analysis of variance (one-way ANOVA followed by Duncan's multiple range test at the 5% level) was performed on data sets, with the mean and SE of each treatment calculated.

3. Results

3.1. Se Concentrations in Each Part of Plants

The Se concentrations of each tissue in wheat and broad bean crops increased with the increasing concentration of Se in the soil (Figure 1), consistent with other findings [10]. A significant difference was found between Se concentrations in different organs of the two crops. The concentrations of Se in the edible organs of wheat (both white flour and bran) were higher than those of broad beans (both cotyledon and testa) within each level of Se in the soil. Se concentrations in whole grain were 3.49 times and 2.52 times higher than those in whole beans with treatments of SeM, and SeH, respectively. Moreover, in terms of wheat, Se concentrations in edible organs were higher than those in inedible organs, but in broad bean, no similar pattern was observed. Additionally, Se concentrations in broad bean root were 2.33 times and 3.22 times higher than those in wheat root with treatments of SeM, and SeH, respectively.

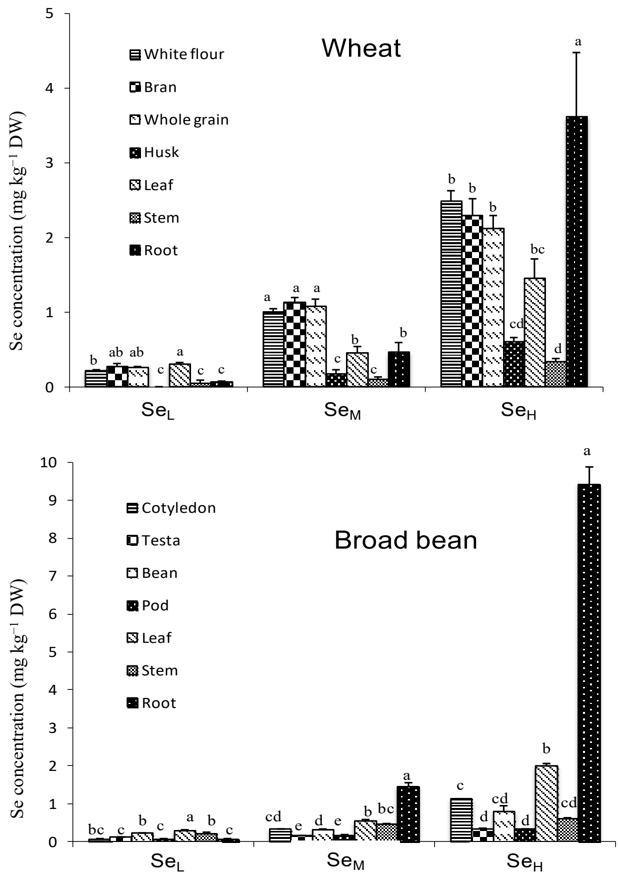


Figure 1. Se concentrations in different tissues (including root, stem, leaf, pod or husk, bean or whole grain, testa or bran, white flour or cotyledon) of wheat and broad bean with different Se concentrations in soil. Values are averages ± standard error of four replicates. Lowercase letters in each Se level indicate significant differences at $p < 0.05$.

3.2. Se Speciation in Edible Parts of Plants

Various Se speciations identified in the edible parts of the plants are shown in Figure 2. For the edible parts of both wheat and broad beans, Se concentrations were determined at very low levels, and most of the Se species detected were organic Se. Meanwhile, the mean concentrations of Se in the samples were quantified as well (Table 1). The sum of all Se speciation in edible organs of wheat was higher than that of broad beans. Among these, the sum of Se speciation in wheat bran was up to about eight times higher than that in broad bean testa with SeH treatment. Of all Se speciations in both wheat and broad bean, SeMet has been shown to be the dominant speciation, followed by SeCys and MeSeCys. The ratio of SeMet to the sum of Se species in the tissues varied from 59.66% to 100%. For the edible parts such as white flour, the concentrations of SeMet and SeCys increased with the increasing concentration of Se in the soil.

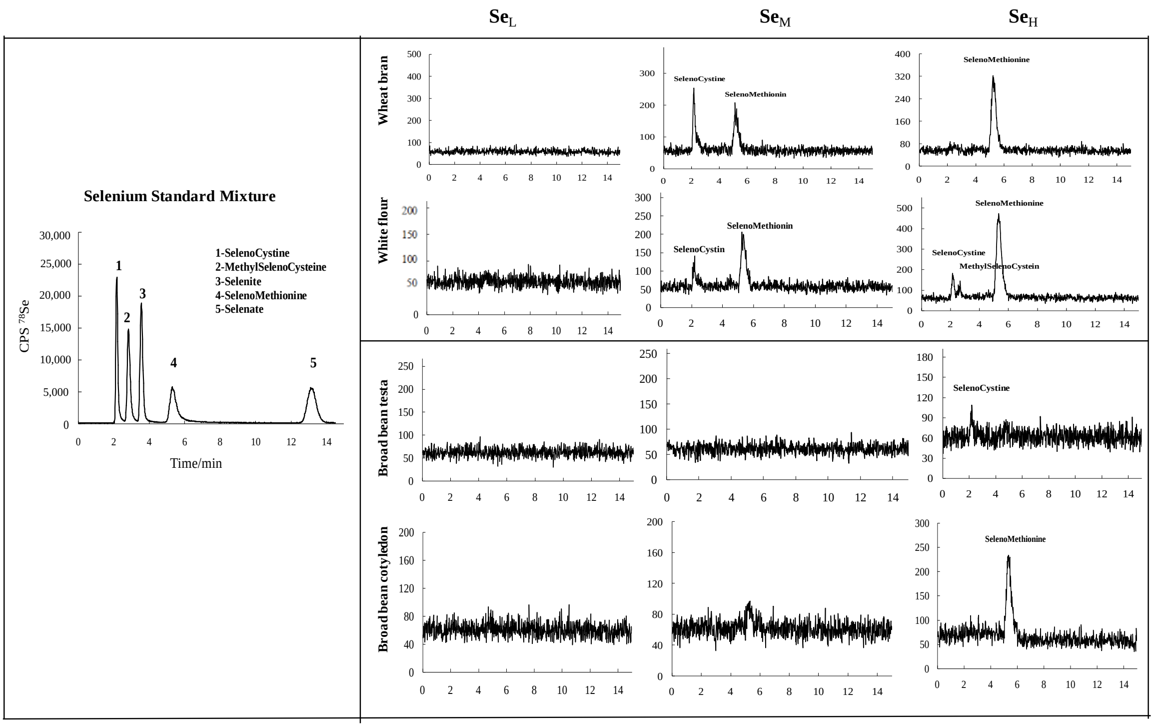


Figure 2. HPLC-ICP-MS detection of Se speciation in protease-extracted edible parts of wheat (or broad bean) with different levels of Se treatment in soil.

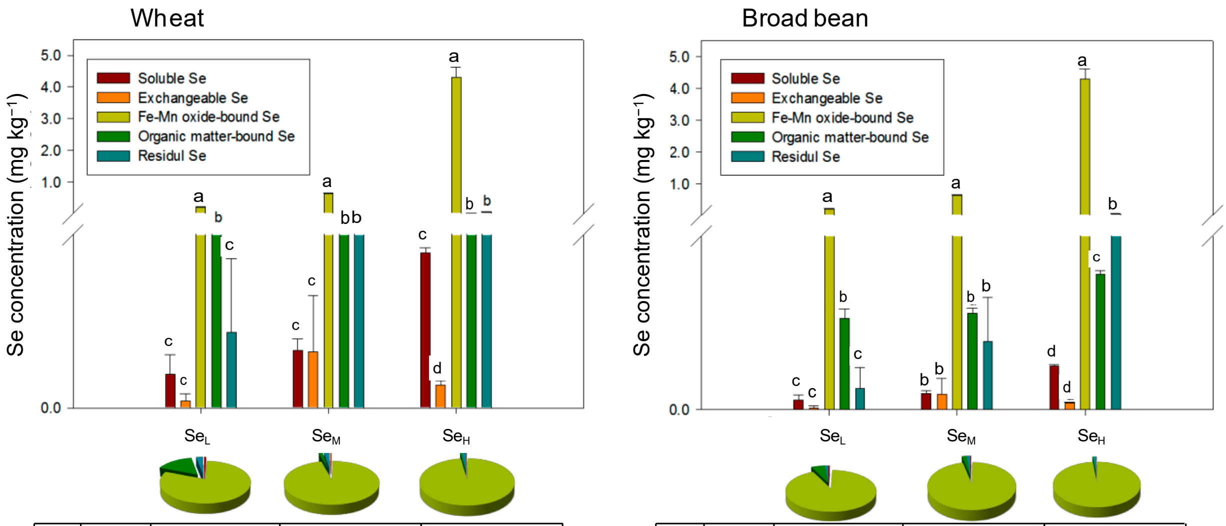
Table 1. Concentrations of Se speciation in edible parts of crops (mg kg^{-1}).

Plant	Parts	Treatment	SeCys	SeMet	MeSeCys	Selenite	Selenate	Sum of Species
Wheat	Bran	Se_L	ND	ND	ND	ND	ND	ND
		Se_M	0.432	0.639	ND	ND	ND	1.071
		Se_H	ND	1.041	ND	ND	ND	1.041
	White flour	Se_L	ND	ND	ND	ND	ND	ND
		Se_M	0.139	0.612	ND	ND	ND	0.751
		Se_H	0.206	1.404	0.137	ND	ND	1.747
Broad Bean	Testa	Se_L	ND	ND	ND	ND	ND	ND
		Se_M	ND	ND	ND	ND	ND	ND
		Se_H	0.120	ND	ND	ND	ND	0.120
	Cotyledon	Se_L	ND	ND	ND	ND	ND	ND
		Se_M	ND	0.228	ND	ND	ND	0.228
		Se_H	ND	0.837	ND	ND	ND	0.837

"ND" stands for "not detected".

3.3. Se Fractions in Soil

As shown in Figure 3, the Se concentrations of the soil increased with the increasing concentration of total Se in the soil. There were statistically prominent differences between different fractions of Se. In both wheat and broad bean soil, Fe-Mn oxide-bound Se was the main ingredient in the soil, and the ratio of Fe-Mn oxide-bound Se to the total Se increased with the increasing concentration of Se in soil, far exceeding the proportion of other forms of Se. In wheat soil, Fe-Mn oxide-bound Se accounted for more than 80% (with a range of 80.27% to 97.40%) of the total Se in soil. In broad bean soil, the concentrations of Fe-Mn oxide-bound Se accounted for 92.36% to 98.21% of the total Se in soil.



		Se_L	Se_M	Se_H
%		0.83	0.29	0.14
		0.00	0.19	0.11
		80.27	95.55	97.40
		15.94	1.66	0.68
		2.96	2.31	1.67

		Se_L	Se_M	Se_H
%		0.59	0.35	0.14
		0.00	0.00	0.02
		92.36	96.12	98.21
		5.73	2.06	0.45
		1.32	1.47	1.18

Figure 3. Se concentration of different fractions and the ratio of the Se fractions to total Se in soil of wheat and broad bean. Values are averages ± standard error of four replicates. Lower case letters in each series indicate significant difference ($p < 0.05$) within every Se level. The pie chart in the bottom represents the proportion of Se fractions to total Se in soil, and the percentage of each fraction Se is listed as well.

Adversely, for both wheat and broad bean soil, the ratio of soluble Se to total Se, as well as the proportion of organic-matter-bound Se and residual Se to total Se, decreased with the increasing concentration of Se in the soil.

3.4. The Character of Se Accumulation in Plant

The Se bioaccumulation factor (BF), the ratio of Se concentration in crop tissues to that in soil, was used to evaluate the efficiency of Se transfer from soil to plant. As listed in Table 2, for both wheat and broad bean, BF values of edible organs decreased with the increasing concentration of soil Se. As for wheat, the BF values of the inedible organs including husk, leaf, stem and root in SeH treatment were higher than those in SeM treatment, while the BF values of broad beans decreased in the SeH treatment compared with the SeM treatment.

Table 2. The bioaccumulation factor (BF) and translocation factor (TF) of Se in plant with different level of Se treatments in soil.

Crop	Se Treatment	BF (Bioaccumulation Factor)					TF (Translocation Factor)			
		Whole Grain (or Bean)	Husk (or Pod)	Leaf	Stem	Root	Whole Grain/Husk (or Bean/Pod)	Husk/Stem (or Pod/Stem)	Leaf/ Stem	Stem/Root
Wheat	Se_L	1.82 [a]	0.00 [b]	2.19 [a]	0.32 [a]	0.49 [b]	0.00 [c]	0.00 [b]	6.81 [a]	0.65 [a]
	Se_M	0.68 [b]	0.11 [a]	0.29 [b]	0.06 [b]	0.29 [c]	6.20 [a]	1.78 [a]	4.69 [b]	0.21 [b]
	Se_H	0.46 [c]	0.13 [a]	0.31 [b]	0.07 [b]	0.78 [a]	3.51 [b]	1.80 [a]	4.34 [b]	0.09 [c]
Broad Bean	Se_L	1.00 [a]	0.21 [a]	1.29 [a]	0.90 [a]	0.27 [b]	4.88 [a]	0.23 [b]	1.43 [b]	3.40 [a]
	Se_M	0.46 [b]	0.23 [a]	0.81 [b]	0.67 [a]	2.15 [a]	1.97 [b]	0.34 [b]	1.20 [b]	0.31 [b]
	Se_H	0.18 [c]	0.08 [b]	0.45 [c]	0.14 [b]	2.15 [a]	2.36 [b]	0.55 [a]	3.27 [a]	0.06 [c]

Data are averages of four replicates. Lower case letters in each series indicate significant difference ($p < 0.05$) within every Se level.

The Se translocation factor (TF) is the ratio of the Se concentration in one crop organ to the Se concentration in another crop organ. Here, it was described that all TF values (except TFHusk/Stem) of wheat tissues decreased in SeH treatment when compared with those in SeM treatment, while the TF values (except TFStem/Root) of broad bean parts increased (Table 2). The results indicated that the conversion of Se from the soil to the edible part of wheat via the stem decreased with the increasing concentration of Se in the soil; however, it increased in broad bean.

3.5. The Relationship of Se Concentration in Edible Parts with Corresponding Se Concentration in Other Tissues and Soil

In Figure 4, there was a significant positive correlation between Se content in whole grain and Se concentration in white flour. Additionally, there were significant correlations between total Se in soil and corresponding edible fractions, including white flour, bran and whole grain, and the R^2 values were up to 0.976, 0.905 and 0.921, respectively. A highly linear correlation also emerged between husk Se and Se in different wheat tissues including white flour, bran and whole grain, with R^2 values of 0.941, 0.807 and 0.749, respectively. There were remarkable linear relationships between stem Se and white flour Se, bran Se and whole grain Se. The high degree of linear correlations was also manifested between root Se and white flour Se, bran Se and whole grain Se. According to the above data, it was not difficult to find that white flour could accumulate more Se than the corresponding bran and the whole grain. Within all edible tissues, white flour Se presented the strongest correlation with Se in the soil, root, and husk.

Regarding broad bean, the content of Se in beans was positively correlated with the content of Se in cotyledons (Figure 5). Furthermore, there were prominent correlations between the total Se in the soil and corresponding edible fractions including the cotyledon, testa and bean, with R^2 values of 0.959, 0.623 and 0.911, respectively. As was demonstrated, significant correlations were also exhebited between root Se concentration and corresponding cotyledon, testa and bean concentrations with R^2 values of 0.975, 0.607 and 0.914, respectively. Remarkable linear relationships were also predent between the concentration of Se in the pod and those in different broad bean fractions including the cotyledon, testa and bean. It seemed that the cotyledon could accumulate more Se than the corresponding testa and bean.

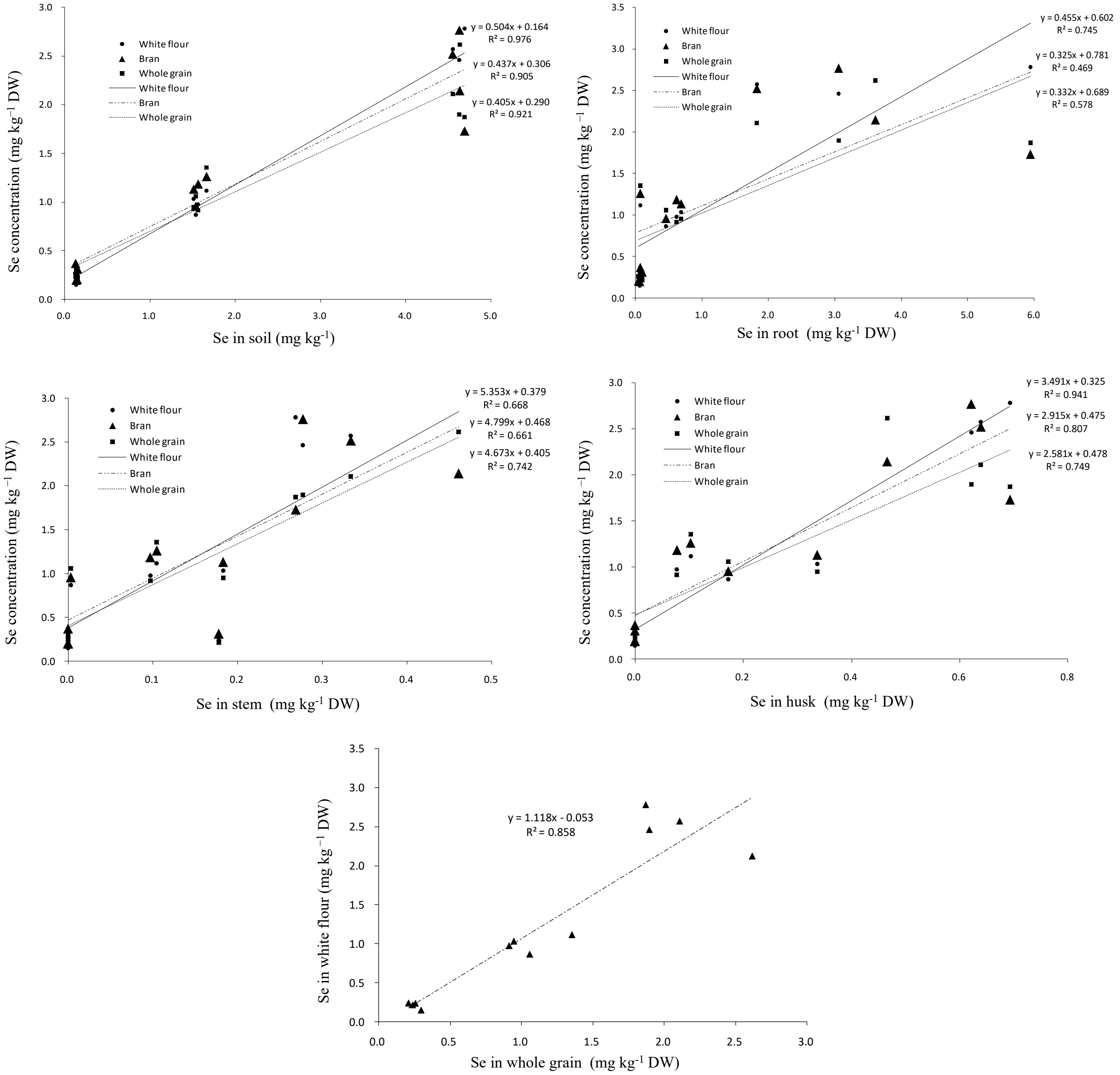


Figure 4. The relationship of Se concentration in whole grain and their corresponding white flour, and the relationship of Se concentration in grain tissues (white flour, bran, whole grain) with corresponding Se in the other wheat fractions (root, stem, husk) and soil.

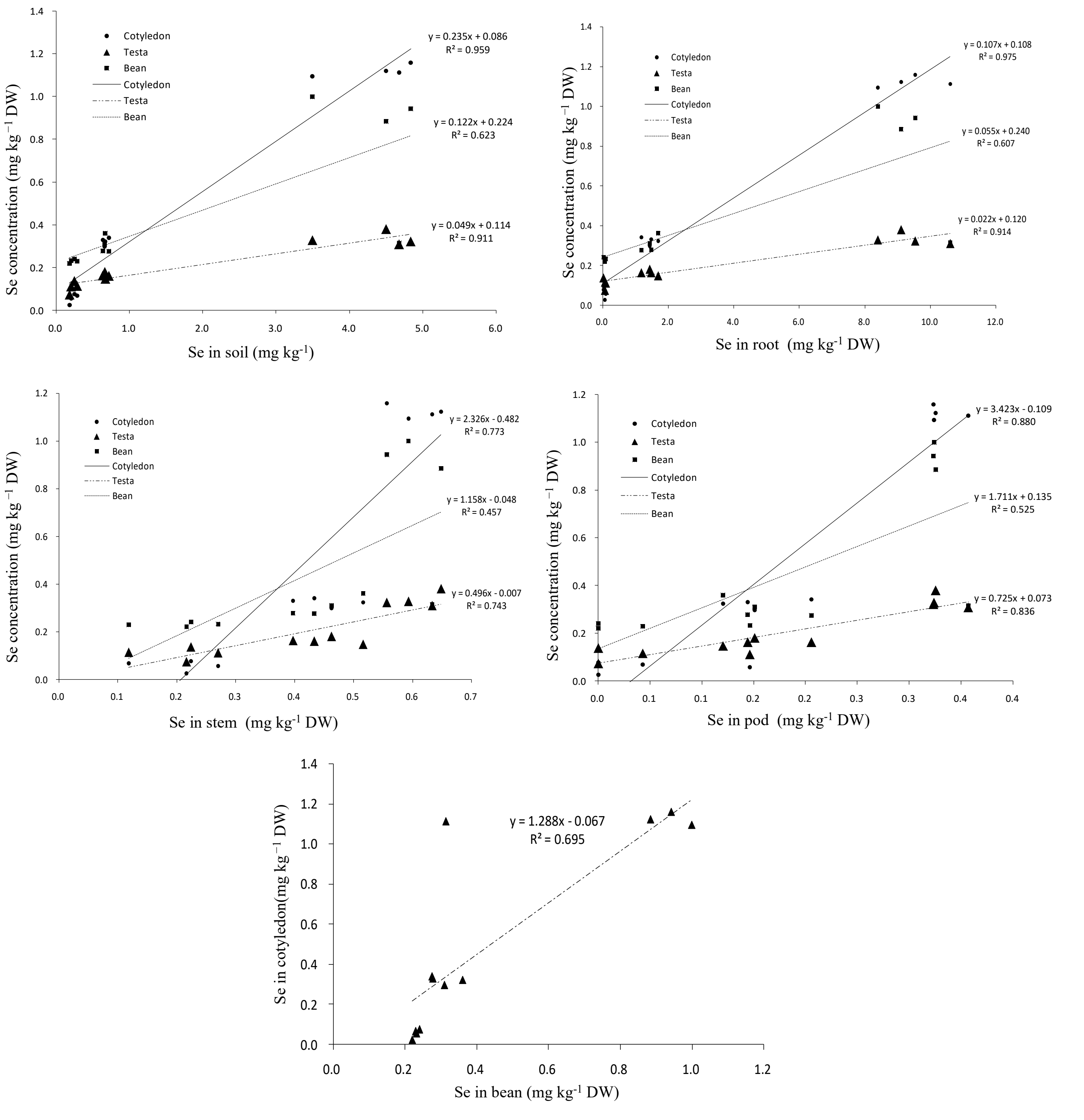


Figure 5. The relationship of Se concentration in bean and their corresponding cotyledon, and the relationship of Se concentration in broad bean tissues (cotyledon, testa, bean) with corresponding Se in other broad bean fractions (including root, stem, pod) and soil.

4. Discussion

Numerous studies have been carried out on the accumulation and distribution of Se in different parts of plants using exogenous Se in field or laboratory experiments [29–31]. Additionally, many of the studies have focused on Se fractions and bioavailability in soils [32–34], or on the relationship between Se in crops and in soil for obtaining Se-enriched food [35,36]. However, few studies have been carried out on Se fractions in the soil and Se speciation in the edible parts of the crops, and even fewer have assessed the differences between wheat and broad beans in the same field or soil.

In this paper, the Se concentration was set based on the team's previous experience, and the plants in the field grew normally without poisoning. In the present study, results from both wheat and broad beans consistently showed that the total concentration of Se in different parts of the plants increased accordingly with the rise in Se concentration in the soil (Figure 1), which is consistent with other studies [10,37]. Besides that, it was also illustrated that the concentrations of Se in the edible tissues of wheat were higher than those in broad bean within each level of Se in the soil. Additionally, concentrations of Se in the edible parts (white flour and bran) were higher than in the inedible parts (except root) of wheat. These findings suggested that the application of Se might alleviate the deficiency of Se in the soil and enhance Se accumulation in crop food, which is beneficial to human health. Meanwhile, a high concentration of Se accumulated in wheat bran which was regarded as a good Se-enriched feedstuff resource for livestock. Se concentrations in different parts of both species were rather distinct. Therefore, suggestions on the selection of plant species that effectively increase the transference of Se from inedible parts to edible parts will contribute to a more effective way of producing Se-enriched food.

For the edible parts of both wheat and broad bean, the determined Se concentrations were at a low level, and most of the Se speciation in edible parts was organic Se—MeSeCys, SeCys and SeMet (Figure 2). While the total organic Se in the edible parts of both crops could be exactly detected, the sum of Se speciation in wheat was higher than in broad bean. These findings suggested that it was more advisable to plant wheat than broad bean in the same field for producing Se-enriched food. In addition, of all Se species in both wheat and broad bean, SeMet has been shown to be the dominant species in bran, white flour and cotyledon, followed by SeCys and MeSeCys (Table 1), which is consistent with previous research such as that performed by Wang et al. and Sun et al. [28,38]. The efficient utility of SeMet has been prone to the human body, including protection from damage to human health [39–41]. Interestingly, SeCys was detected in the testa but not in the cotyledon. These results could be largely due to the fact that inorganic Se was taken up in the plant and first transformed to SeCys, and subsequently, the other species of Se were derived from SeCys [42]. In this study, the fact that SeCys was not detected in cotyledons might be because it has been converted into other organic forms, due to SeCys being the precursor for the formation of other organic Se compounds [28,43]. In accordance with the results, selenate and selenite were not detected in the edible tissues of both wheat and broad beans (Table 1). The outcome of the present study indicated that the application of selenite in soil increased the organic forms of Se concentration in the edible parts of the crops but did not cause the accumulation of selenate and selenite.

The concentration of Se in plants depends more on the fractions and speciation of Se than on the total Se in the soil, because most soil Se cannot be easily absorbed except for organic Se [18,26,44]. In this study, the results showed that there were striking distinctions among different fractions of Se in the soil (Figure 3). For both wheat and broad bean soil, Fe-Mn oxide-bound Se was the primary speciation in the soil. With the rising concentration of Se in wheat soil, the proportion of Fe-Mn oxide-bound Se to the total Se increased, while the ratios of soluble Se as well as organic-matter-bound Se and residual Se to total Se decreased. However, with the increasing concentration of Se in broad bean soil, only the rate of soluble Se and organic-matter-bound Se decreased. Our findings revealed that wheat was more effective at Se transference and accumulation during the tillering stage than during the grain formation stage. Here we calculated the BF values, and the results uncovered that the BF values of wheat roots were much lower than those of broad bean under the same level of Se treatment (Table 2). It was indicated that wheat could accumulate more Se in aerial parts while broad beans could accumulate more in roots with Se application. Compared with SeM treatment, all TF values (except TFHusk/Stem) of wheat tissues decreased, while the TF values (except TFStem /Root) of broad bean tissues increased (Table 2) in SeM treatment.

Additionally, the linear relationships of Se in parts of crops and in soil illustrated that Se concentrations in edible tissues can be predicted using the Se concentrations in other parts of the plant including total Se in soil, roots, stem, husk and pod (Figures 4 and 5).

It is reasonable to explain that the Se concentration in the edible parts of both wheat and broad bean increased with the growth of Se concentration applied to soil. In that case, the concentrations of Se in the edible parts of the two crops can be predicted using the Se concentrations in other parts of the crops and in the soil [36,45]. In particular, the present study provided a theoretical basis for selecting enrichment of Se in different parts of crops under different concentrations of Se in the soil. Se in edible parts had significantly positive correlation with other parts in crops and different Se fractions in the soil, which might play a vital role in predicting Se enrichment and promoting the bioavailability of edible parts.

5. Conclusions

The current study demonstrated that the augmentation of Se supplies in soil contributed to the improvement of Se concentration in the edible parts of both wheat and broad bean. It was quite clear that the concentration of Se in the edible parts of wheat was higher than in broad beans. For the edible parts of both wheat and broad bean, Se concentrations were determined to be low, and most of the Se speciation was organic Se. Organic Se speciation in the edible parts of wheat was higher than that of broad bean within the same level of Se treatment in the soil. Of all organic Se, SeMet has been shown to be the dominant species, followed by SeCys and MeSeCys. Apart from that, Fe-Mn oxide-bound Se was the dominant fraction in both wheat and broad bean soil. It also displayed positive efficiency of the relationship between BF values in wheat plants and Se concentration in the soil, while it displayed negative efficiency of the relationship between BF values in broad beans and Se content in the soil. In general, TF values in wheat tissues decreased at high levels of Se treatment; however, the TF values in broad bean tissues increased. Overall, for both wheat and broad bean, concentration of Se in the edible parts had a significantly positive correlation with that in the other parts of the crops, as well as Se fractions in the soil.

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