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CHARACTERIZATION OF GENOTYPE VARIATION AND AGRONOMIC BIOFORTIFICATION OF COWPEA WITH SELENIUM: IMPACTS ON PHYTIC ACID AND NUTRITIONAL QUALITY OF GRAINS

Ilha Solteira
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Dissertation presented to the Engineering College of Ilha Solteira – UNESP as part of the requirements to obtain the title of Master in Agronomy. Specialization: Production Systems

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“Somewhere, something incredible is waiting to be known”
Sharon Begley - August 15, 1977, Newsweek magazine

RESUMO

O selênio (Se) é um nutriente para humanos e animais e um elemento benéfico para as plantas, sua baixa concentração nos solos do Brasil pode gerar deficiência nos animais e humanos. O fitato é a principal forma de reserva de fósforo (P) encontrado nas sementes de plantas, sendo considerado um "anti-nutriente" por formar complexos não digeríveis com nutrientes como Fe, Ca e Zn. Desta forma, existe a necessidade de se buscar alternativas para aumentar os teores de Se e reduzir o teor de fitato nas partes comestíveis de cultivares modernos. O objetivo do trabalho foi avaliar doses e fonte ótimas de Se a serem aplicadas em condições brasileiras, bem como a influência do Se na produção e qualidade nutricional em 29 genótipos de feijão-caupi. Para isso, foram desenvolvidos dois experimentos a seguir: Experimento 1: Foi avaliada a eficiência da biofortificação agronômica utilizando 2 fontes de Se (selenato e selenito) e 7 doses de Se (0; 2,5; 5,0; 10,0; 20,0; 40,0 e 60 g ha^{-1}) aplicados via solo, foi realizada analise de fitatos nos grãos. Experimento 2: Foi realizado um experimento para caracterizar a absorção e acúmulo de Se, teor de fitatos, açucares, proteínas de reversa e amino ácidos nos grãos de diferentes genótipos de feijão-caupi, nesse experimento, 29 genótipos foram avaliados na presença e ausência de Se (0 e 25 g ha^{-1}), cultivados até o final do ciclo para a obtenção dos grãos. No experimento 1, observou-se que a aplicação de selenato proporciona maiores concentrações de Se nos grãos em comparação com o selenito. A aplicação de Se não teve influencia direta na concentração de fitatos nos grãos. No experimento 2 observou-se que os a aplicação de Se aumentou a concentração do elemento nas raízes, parte aérea e principalmente grãos de todos os genótipos avaliados. A aplicação de Se pode proporcionar aumento, diminuição ou não influenciar o teor de fitatos, açúcares, proteínas de reserva e aminoácidos, dependendo do genótipo.

Palavras-chave: Biofortificação agronômica. Feijão-caupi. Variação genotípica. Selênio.

ABSTRACT

Selenium (Se) is a nutrient for humans and animals, and a beneficial element for plants, its low concentration in Brazilian soils might cause deficiency in animals and humans. Phytate is the main form of phosphorus (P) storage found in plant seeds, being considered an "anti-nutrient" by forming nondigestible complexes with nutrients such as Fe, Ca and Zn. Thus, there is a need to find alternatives to increase Se and decrease phytate concentration in the edible parts of modern cultivars. The objective of this study was to evaluate optimal levels and sources of Se to be applied in Brazilian conditions, as well as the influence of the Se in the production and nutritional quality in 29 genotypes of cowpea. Two experiments were performed: Experiment 1: The efficiency of agronomic biofortification was evaluated using 2 sources of Se (selenate and selenite) and 7 levels of Se (0; 2.5; 5.0; 10.0; 20.0, 40.0 and 60 g ha^{-1}) applied via soil, phytate analysis was analyzed. Experiment 2: An experiment was carried out to characterize the uptake and accumulation of Se, phytate, sugars, storage proteins and amino acids in the grains of different genotypes of cowpea. In this experiment, 29 genotypes were evaluated in the presence and absence of Se (0 and 25 g ha^{-1}), grown until the end of the cycle to obtain the grains. In experiment 1, it was observed that the application of selenate provides higher concentrations of Se in the grains compared to selenite. Selenium application showed no direct influence on the phytate concentration in the grains. In experiment 2 it was observed that the application of Se increased the concentration of the element in roots, shoot and grains of all evaluated genotypes. Se application may provide increase, decrease or not influence the content of phytates, sugars, reserve proteins and amino acids, depending on the genotype.

Keywords: Agronomic biofortification. Cowpea. Genotypic variation. Selenium.

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ITRODUCTION

Foods as a primary source of nutrients and its demand grows with the increasing of worldwide population. In 1800, the world's population was 1 billion. Currently, with an average growth rate of 1.37%, the worldwide population is 6.9 billion people (RAYMAN, 2012). For 2050, it is estimated that the worldwide population hits 9.4 billion people.

The cereal yield has maintained the same rising rate of the worldwide population. It is estimated that the global demand for food may double in the period between 1990 and 2030, with a two and a half to three-fold increase in developing countries (GARVIN; WELCH; FINLEY, 2006). On the other hand, the malnutrition has increased reaching almost half of the world's population, especially pregnant women, teenagers and children (GRAHAM et al., 2007). This is, in part, due to plant breeding aiming to yield increasing, and thus, presenting an inverse relation with mineral content in grains (GARVIN; WELCH; FINLEY, 2006; MURPHY; REEVES; JONES, 2008; WHITE et al., 2009).

Selenium is considered a scarce element, with irregular distribution in earth's crust, and besides the origin material, its content in soil depends highly on water regime of each region (HAUG et al., 2007). The levels of Se in agricultural food products are strongly dependent on the presence of this element in the soil and also on the regulation in function of plant species/genotype, although due to the few studies carried out, there are doubts about the agronomic significance of the variation/genotypic regulation in their accumulation in cultivated plants (LYONS et al., 2005). The Se when supplied in the source of selenate competes with Sulfur (S) transporters, and when supplied in the source of selenite competes with the phosphate transporters in plants (REIS et al., 2017a).

The phytic acid (or myo-inositol hexaphosphate, or InsP6 or IP6) is the main compound of phosphorus (P) storage in seeds, its found in salt named phytate and comprises between 60 and 90% of all P in cereals, oilseeds and nuts (LOTT et al., 2000; 2001; BOHN; MEYER; RASMUSSEN, 2008). The phytic acid and its derivates (mainly IP5) bound to metallic ions in pH values similar to duodenum (CARLI et al, 2006). Therefore, phytate is considered an antinutrient, able to for insoluble complexes with minerals, proteins, enzymes and starch, a trait that can impair in the absorption of Calcium (Ca), Magnesium (Mg), Copper (Cu), Fe and Zn, primarily, when the intake of this minerals in inadequate (GRAF; EATON, 1990; PRYNNE et al, 2010). Among the problems caused by phytate, there are severe deficiencies in populations with diets composed primarily by cereals and pulses, mostly in vulnerable groups, such as young, and pregnant women in needy regions that commonly ingest low quantities of Ca, Fe, Mg e Zn (WEAVER; KANNAN, 2002). Thus, regarding the food security, is important to research for means to reduce the levels of phytate in plant seeds used as food, mostly the ones important in needy regions, as the cowpea.

The agronomic biofortification with Se increases the nutritional quality of food (RAYMAN, 2012) and the potential to reduce phytate in grains turns necessary a better knowledge of the Se accumulation influence in the synthesis of this antinutrient, as well as the influence of Se in the quality of cowpea, that is one of the most important sources of protein in Brazilian northeast, region that presents the greatest rates of malnutrition in the country.

CONCLUSION

Agronomic biofortification of crops with Se should be studied to provide new information on specific quantities of Se supplied for edible crops. The mechanisms of assimilation of Se are studied mostly in situations where Se shares similarities with other elements, for instance, selenite and its similarities with phosphate specifically in the transport from soil to roots. Selenium also share similarities with sulfate and S, but ins this case, not only on uptake from soil to roots, but also within the plant, in its transport to xylem sap and assimilation in organic forms of SeCys and SeMet.

Because PA is a P storage form in seeds and an important compound for seed germination, studies examining the effects of decreased PA concentrations on germination are also extremely relevant. Although decreased PA concentrations may improve the quality of the consumed food, the importance of P accumulation in seeds and crop germination cannot be overlooked so the high yield standards achieved by the crop plant genotypes and varieties commonly used for food production are maintained.

The uptake of applied Se in cowpea plants is tightly dependent on Se source (selenate or selenite). Application of 10 g ha^{-1} of Se as sodium selenate provided safe and beneficial seed Se concentrations, which have the capability to increase daily human Se intake to between 12.8 and 13.9 µg day^{-1}. Phytic acid concentration in seeds showed no relation to Se application rate and source.

Sodium selenate application increased the Se concentration in roots, shoots and grains from all genotypes tested. At least twofold changes in total Se concentration in grains between genotypes with low and high Se concentration was found, this study provides valuable information for the effect of Se on plant growth and metabolism of cowpea genotypes. This information can be used in future breeding programs to select better genotypes for Se genetic biofortification in cowpea plants.

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