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# Impact of Inadequate Concentration of Boron in Seed Storage Proteins Content in Oilseed Crops

*Archana, Preetam Verma and Nalini Pandey*

## Abstract

For the estimation of Impact of inadequate concentration of boron in seed storage proteins content in oilseed crops, a sand culture experiment was designed and all the three crops i.e. soyabean, mustard and linseed were grown under sufficient and insufficient boron treatment till maturity. Seed germination and seed storage protein concentration was determined in seeds after the harvesting of crops. Earlier oilseed crops like soyabean, mustard and linseed are cultivated for oil production but at this time these crops are reliable source of protein also and are real asset for human dietary protein. The storage protein present in seeds varies from ~10% (in cereals) to 40% (in certain legumes and oilseeds) of dry weight. Seeds contain one or more groups of proteins that are present in high amounts and that serve to provide a store of amino acids and sulfur required during germination and seedling growth. Quality of seeds is driven by the total protein content present in the form of storage reserve in seeds. There are major four types of storage proteins known as-globulins (insoluble in water), albumins (soluble in water), prolamins (soluble in alcohol) and glutelins (soluble in dilute acid and alkaline medium). Globulins and albumins are the major storage seed proteins of legumes and oilseed crops whereas prolamins and glutelins are mostly found in cereal seeds. Functionally boron is crucial micronutrient for a considerable amount of agricultural yield. Seed reserves (proteins, carbohydrates, starch, lipids) of post harvested seeds are depended on the appropriate boron supply during cropping. Boron insufficiency in oilseed crops found to be an inhibitory factor for seed vigor and seed quality. So this chapter deals with the effect of boron deprivation on seed quality in terms of germination capacity and seed storage protein reserves in the post harvested seeds of soybean, mustard and linseed.

**Keywords:** boron, oilseed crops, storage proteins, seed germination, seed yield

## 1. Introduction

Boron is essential for appropriate reproductive blooming in crops. Reproductive growth is more sensitive to boron deficiency and failure in pollination, abscission of reproductive organ or falling of young fruits are typical symptoms of deficiency [1]. The boron requirement is much higher for reproductive growth than for vegetative

growth in most plant species. Boron increases flower production and retention, pollen tube elongation and germination and seed and fruit development. The reproductive growth especially flowering, fruit and seed set and seed yield is more effective even at moderate boron insufficiency than vegetative growth [2, 3]. Various reports in many crops exhibited that boron can be inadequate and have a notable impact on yield even when there are no vegetative symptoms of boron insufficiency and supply of boron is also adequate [4, 5]. Shedding of buds, flowers and developing fruits and seeds as well poor fruit/seed quality and poor seed viability are seen in crops grown under inadequate boron at the onset of reproductive blooming [6].

Male sterility and retarded microsporogenesis and pollen fertility in wheat due to poor translocation of boron from vegetative to reproductive parts is the main cause of poor grain yield [7]. Post fertilization development and seed maturation is also influenced by the boron nutrition. Poor germination and vigor of seeds was reported in low boron crops [8]. Increment in phenolic compounds and fall in oil content in seeds of *Sesamum* plants receiving inadequate boron nutrition was spotted by Sinha *et al.* [9]. Chatterjee and Nautiyal [10] reported that boron deprivation in sunflower caused morphological aberrations in seeds and bring down the seed content of non-reducing sugars, starch and oil, even at the commencement of anthesis.

The demand of boron nutrition at the time of flowering and seed set is much higher in many crops even when boron concentration in vegetative organs are in appropriate amount Increased abnormal seedlings and decreased germination rate during seed germination was observed in boron insufficient seeds [8, 11, 12]. Various workers have reported that there is an enhancement in fruit set and yield with boron foliar fortification [5, 13]. The same was observed during the reproductive stage of sunflower leads to increment in seed yield suggesting involvement of boron in reproductive biology [4] and also qualitative and quantitative improvement in strawberry fruits [14].

Dordas [15] mentioned the consequences of boron foliar fertilizers on pod development, pod set, seed set, seed yield and yield components such as pod number per inflorescence, seed number per pod, seed development, seed weight, and on seed quality in terms of seed germination and seed vigor and observed that the seed yield was enhanced approximately 37% and seed germination and seed vigor improved upto 27% in alfalfa as compared to untreated control. They also noticed that the critical boron levels for alfalfa used for forage production is below that for seed production and boron foliar fertilization can enhance the seed yield and seed quality of alfalfa grown for seed production. Pandey and Gupta [16] reported improved seed yield and seed vigor in the boron insufficient black gram plants given foliar application of boron. They also reported improved seed quality in terms of storage seed proteins (albumin, globulin, glutenin and prolamin) and carbohydrates (sugars and starch) in black gram received foliar boron fertilizer. The reality of that boron implementation improved seed vigor specifies that seeds with adequate boron nourishment can germinate and produce seedlings with better ability to grow and resist any adverse environmental conditions. This is in agreement with the suggestion that seeds that were developed in plants with adequate nutrient supply show high germination percentage and also have high seed vigor [17].

The essentiality of boron suggests that there is a continuous requirement of it during the entire growth period of plants. There is a critical requirement of boron for reproductive development and seed quality which must be met at the onset of the reproductive phase. Thus boron deficiency is a major factor responsible for low seed yield and quality of oil yielding crops widely cultivated on boron deficient soils world over. The aim of the research work conducted is to put together the effect of boron on reproductive development, production, maturation and nutritive quality

of soybean, mustard and linseed seeds. In agriculture especial attention is required for achieving higher production and productivity levels in agricultural and horticultural crops which are essential for nutritional security. Thus the crops chosen for the work are the widely consumed soybean, mustard and linseed as they meet the daily cooking oil requirement in India. This chapter also suggests that there is an adequate requirement of boron nutrition to improve seed quality in terms of germination capacity and seed storage protein reserves in the post harvested seeds of soybean, mustard and linseed.

## 2. Experimental design and material and methods

Design of experiment is completely randomized and selection of plants was seasonal based during the work carried out in the laboratory. Plants were raised in the glass house under controlled conditions of light (light (PAR) ranged between 1050 to 1180  $\mu\text{mol m}^{-2} \text{s}^{-1}$  at 12.00 noon), humidity (80–92%) and temperature (maximum and minimum temperature ranged between 37 and 43°C and 28 and 34°C respectively).

**Sand culture:** Soybean (*Glycine max* var. JS-335), mustard (*Brassica juncea* var. varuna) and linseed (*Linum usitatissimum* var. R-552) were grown in sand culture using the technique developed at the Long Ashton Research Station, Bristol, U.K. [18] and standardized for Indian conditions by Agarwala and Sharma [19]. The composition of nutrient solution used for growing the plants excluding B was: 4 mM  $\text{KNO}_3$ , 4 mM  $\text{Ca}(\text{NO}_3)_2$ , 2 mM  $\text{MgSO}_4$ , 1.33 mM  $\text{NaH}_2\text{PO}_4$ , 0.1 mM Fe EDTA, 10  $\mu\text{M}$   $\text{MnSO}_4$ , 1  $\mu\text{M}$   $\text{CuSO}_4$ , 1  $\mu\text{M}$   $\text{ZnSO}_4$ , 0.1  $\mu\text{M}$   $\text{Na}_2\text{MoO}_4$ , 0.1 mM NaCl, 0.1  $\mu\text{M}$   $\text{CoSO}_4$  and 0.1  $\mu\text{M}$   $\text{NiSO}_4$ . Boron was supplied as  $\text{H}_3\text{BO}_3$  at varying levels as sufficient amount (0.33  $\text{mg L}^{-1}$  B supply) and insufficient (0.033  $\text{mg L}^{-1}$  B supply) amount.

**Seed germination:** Seeds of all crops were first surface-sterilized with 5% (v/v) mercuric chloride solution and washed properly with deionized manesty still water (MSW) before germination. Sterile seeds were then sown in petridishes lined with three fold filter paper in double distilled water at 28°C and 85% relative humidity in seed germinator. The percentage germination of post harvested seeds of all crops was recorded after 48 h.

**Seed protein:** Seed protein was extracted by the method of Sommour [20]. After the harvesting of crops seeds were collected and seed coat was removed and seeds were ground in acetone. The extract was centrifuged 3–4 times at 11,500  $\text{xg}$  for 10 min. Portions of air dried seed flour (200 mg) were extracted with water for albumins, 5% NaCl for globulins, 0.1 N NaOH for glutenins and 70% ethanol with 2 drops of mercaptoethanol for prolamines at room temperature. The proteins in the above extracts were estimated by the method of Lowry et al. [21]. The optical density of the reaction mixture was measured on spectrophotometer at 750 nm. The readings were referred to a standard calibration curve prepared from crystalline bovine serum albumin.

## 3. Oilseed crops

Oilseed crops have been the backbone of agricultural economy of India from times immemorial. Today these crops are cultivated on about 26.67 million hectares, with total production of 30.06 million tonnes [22]. This area constitutes approximately one-tenth of the total cultivated area in India. On the oilseed map of the world, India occupies a prominent position, both in regard to acreage and

production. Oilseed crops are grown primarily for the oil contained in the seeds. The major world sources of edible seed oils are soybeans, sunflowers, rapeseed, cotton and peanuts. Seed oils from Flax (linseed) and castor beans are used for industrial purposes. Oilseed crops used for experimental work in the present study are:

**Soybean:** The soybean (U.S.) or soya bean (UK) (*Glycine max*) is a species of legume native to East Asia and originated in China. It is also known as a 'miracle crop' with over 40% protein and 20% oil. The plant is classed as an oilseed rather than a pulse. Soybean oil contains significantly greater amount of omega-6 fatty acids in the oil: 100 g of soybean oil contains 7 g of omega-3 fatty acids to 51 g of omega-6: a ratio of 1:7. Flaxseed, in comparison, has an omega-3: omega-6 ratio of 3:1. Soybeans also contain the isoflavones genistein and daidzein, types of phytoestrogen, that are considered by some dietitians and physicians to be useful in the prevention of cancer and by others to be carcinogenic and endocrine disruptive. Soy's content of isoflavones is as much as 3 mg g<sup>-1</sup> dry weight. Isoflavones are polyphenol compounds, produced primarily by beans and other legumes, including peanuts and chickpeas [23]. The major unsaturated fatty acids in soybean oil triglycerides are 7%  $\alpha$ -linolenic acid (C-18:3); 51% linoleic acid (C-18:2); and 23% oleic acid (C-18:1). It also contains the saturated fatty acids 4% stearic acid and 10% palmitic acid. The soybean seed storage proteins are classified in 8-conglycinin (7S) and glycinin (11S) proteins and multiple genes are responsible for their production [24]. The seed storage proteins of soybean are reported to be devoid of the S-containing essential amino acids, methionine and cysteine. Seed proteins consist of subunits dissimilar in amino acid profile i.e. 8-subunit of 7S protein. Approximately 60% 11S proteins consisting 3–4.5% sulfur amino-acid content and 40% 7S proteins consisting >1% sulfur amino-acid content are present in storage protein of soybean crops [25, 26].

**Mustard:** Rapeseed mustard (*Brassica*) contributes 32% of the total oilseed production in India, and it is the second largest indigenous oilseed crop. This species is of Asiatic origin and grows in southern regions of the Former Soviet Union, the Caucasus, Western and Eastern Siberia, the Far East, Central Asia. Generally it is also distributed in Middle Europe, Asia Minor, Iran, Afghanistan, India, Mongolia, China, Japan. *Brassica juncea* infests all spring crops including grain and tilled crops, and vegetable gardens. This plant is cultivated as an oil crop and for preparation of mustard powder in the south-east of the European part of Russia, in Ukraine, Belorussia and the North Caucasus. Seeds of *B. juncea* contain 25–30% fatty non-drying oil and glycoside sinigrine. Oilcake is used for preparation of mustard powder. Leaves are used for food in salads, they contain up to 150 mg of ascorbic acid. *B. juncea* is a good bee plant. Transgenic Indian mustard are also useful in phytoremediation of heavy metals and metalloids such as Cd, Cr, Cu, Mn, Zn, Pb, Hg, As, and Se [27, 28]. Indian mustard (*Brassica juncea*), are suitable target species for this strategy because of having a large biomass production, a relatively high trace element accumulation capacity [29], and can be genetically engineered [28]. Mustard oil is a healthy cooking medium because of low saturated fatty acids (8%), high monosaturated fatty acids (70%) and  $\alpha$ -linolenic acid (10%) [30]. The mustard seeds are rich in lysine with considerable amounts of sulfur containing methionine and cysteine amino acids. Thus the mustard seed protein is the excellent source of human nutrition [31]. The most common seed storage proteins found in the cotyledons is cruciferin and napin. Cruciferin proteins are of 12S legumin-like globulin protein with mol wt 300-360 kDa and napins belongs to 2S prolamin-super family albumin with mol wt 12.7–20.3 kDa. These both proteins are differing in molecular forms, amino acid profiles as well as physico-chemical and biological properties.

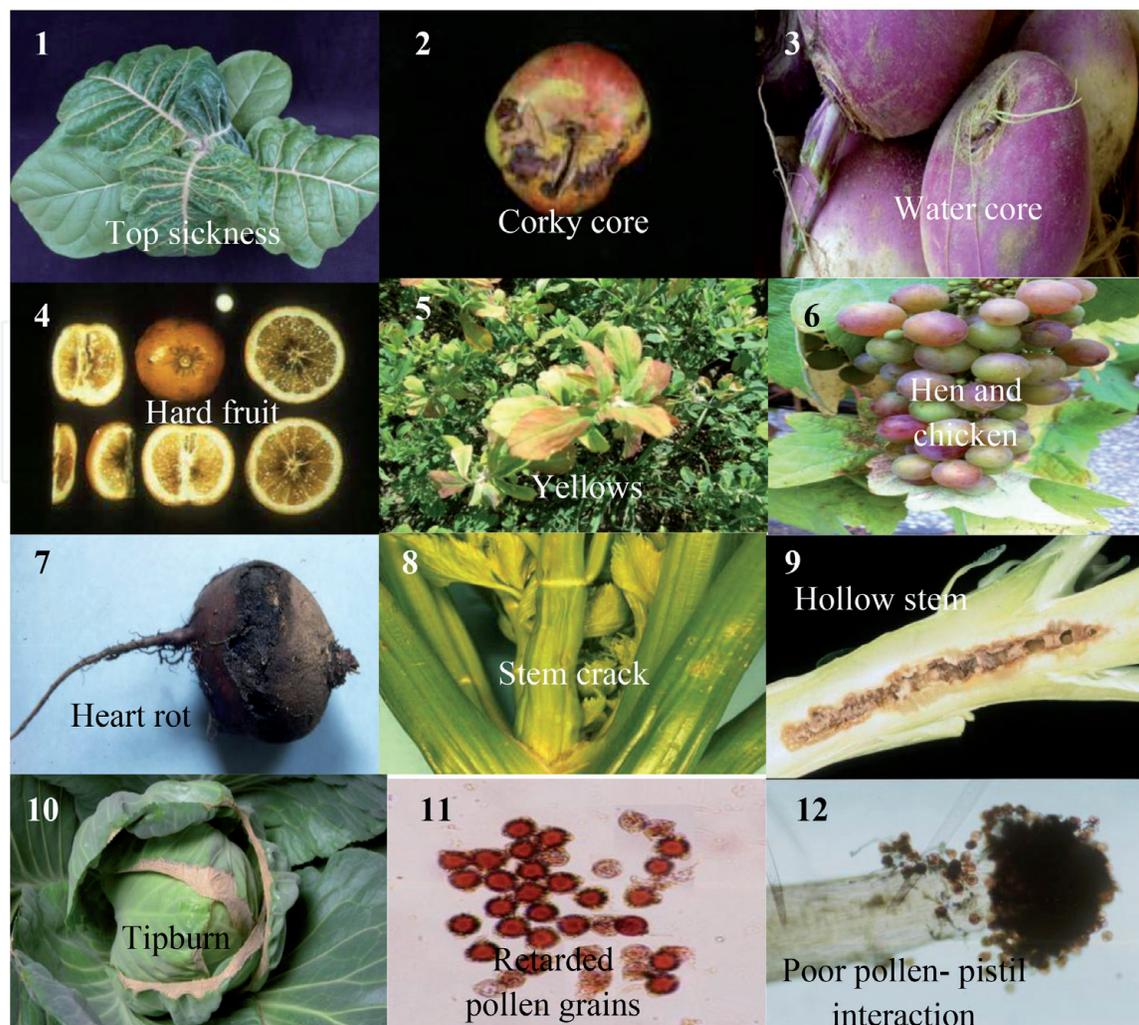
**Linseed:** Flax also known as common flax or linseed (*Linum usitatissimum*) is a member of the family Linaceae. It is native to the region extending from the eastern Mediterranean to India and was probably first domesticated in the Fertile Crescent. Flax seeds contain high levels of lignans and omega-3 fatty acids. Lignans may benefit the heart; possess anti-cancer properties and studies performed on mice found reduced growth in specific types of tumors. Initial studies suggest that flaxseed taken in the diet may benefit individuals with certain types of breast and prostate cancers [32, 33]. Linseed oil is a rich source of linolenic acid (40–60%), an omega 3 fatty acid which has anti-inflammatory action in the treatment of arthritis. It also helps in lowering down the cholesterol level in mammals. Lignan present in oil has anti-carcinogenic effect [34]. Legumin- like proteins of mol wt  $320 \pm 20$  and subunit mol wt of 55, 54.5, 50, 45, 43 and 41 is the characteristic feature of majority of linseed seed proteins. These proteins contain non-covalently bound carbohydrates with pI- values 4.5 to 8. The 2- mercaptoethanol reduces the legumin-like protein polypeptides into acidic and basic subunits with mol wt 25–40 and mol wt 18–22 respectively. Albumin-like proteins contained major subunit with mol wt 25 and minor subunit with mol wt 11 [35]. Sammour et al. [35] also reported that metabolic or antimetabolic activity is not performed by both types of subunits and their storage functioning is found to be due to abundance in nitrogenous amino acids.

#### 4. Boron

Boron is a member of the subgroup III of metalloids and has intermediate properties between metals and non-metals. The boron atom is small and has only three valencies and has a strong affinity for oxygen. Boron is present in soil solution in different forms-  $\text{BO}_2^-$ ,  $\text{B}_4\text{O}_7^-$ ,  $\text{BO}_3$ ,  $\text{H}_2\text{BO}_3^-$  and  $[\text{B}(\text{OH})_4]$ . As an uncharged molecule, its permeability coefficient for transport across the lipid bilayer is several orders of magnitude higher than that of ions. The physical and chemical properties of boron and its complexes are unique and highly varied. Under physiological conditions and in the absence of interaction with bio-molecules, boron exists as boric acid ( $\text{B}(\text{OH})_3$ ) or borate anion ( $\text{B}(\text{OH})_4^-$ ). Boric acid is a very weak acid, with a pKa of 9.24 a cytoplasmic pH (pH 7.5), more than 98% of boron exists in the form of free  $\text{B}(\text{OH})_3$  and less than 2% exists as  $\text{B}(\text{OH})_4^-$  [36]. At pH values found in the apoplast (pH 5.5), greater than 99.95% of boron is in the form of  $\text{B}(\text{OH})_3$  and less than 0.05% is in the form of  $\text{B}(\text{OH})_4^-$ . Boric acid and borate however can readily react with many kinds of biological molecules and under normal biological conditions available boron binding molecules exceed the concentration of free boron. An understanding of boron binding reactions is therefore central to an understanding of boron physiology [37].

Boron is widely distributed in lithosphere and hydrosphere, boron concentration ranging from 5 to 10  $\text{mg kg}^{-1}$  in rocks [38], 3–30  $\mu\text{g kg}^{-1}$  in rivers [39] and ~ 4.5  $\text{mg L}^{-1}$  in ocean [40]. Boron is found mostly in the topsoil. Dry weather reduces moisture in the topsoil and boron uptake by the plant, causing boron deficiency. Even high rainfall areas witness leaching out of borosilicate from the soil, which leads to boron deficiency. Boron deficiency is the most widespread micronutrient deficiency in agricultural crops in world including India. The symptoms of boron deficiency are observed when boron content in soil comes down to 5 to 25  $\text{mg ha}^{-1}$ . Aluminum hydroxide adsorbs large amounts of soluble boron, making the soil acidic and causing boron deficiency. Soils containing a high proportion of organic matter are less deficient in boron.

Some specific symptoms found in plants grown under inadequate boron nutrition are: 'Top sickness' of tobacco; 'Corky core' or 'internal cork' or 'drought spot' of



**Figure 1.** Various symptoms in plants received inadequate boron nutrition (data source online except 11 and 12 these are original data from our experiment).

apple; ‘Water core’ of turnip; ‘Hard fruit’ of Citrus; ‘Yellows’ of alfa alfa; ‘Hen and chicken’ of grapes; ‘Heart rot’ of sugarbeet; ‘Stem crack’ of celery; ‘Hollow stem’ of cauliflower and broccoli and ‘Tipburn’ of chinese cabbage ([41, 42]; **Figure 1**). Boron deficiency also creates an unfavorable situation for the pollen-stigma interaction and limits fertilization leading to poor reproductive yield ([42]; **Figure 1**). Boron takes part in various vital functioning of crops like translocation of sugars, metabolism of RNA, protein, indole acetic acid, phenols, ascorbate, osmotic and oxidative stress etc. [1, 43, 44].

## 5. Storage proteins

Seed yield is a complex trait as it is the product of several individual yield components such as number of inflorescences per plant, number of pods per inflorescence, number of pods per plant, number of seeds per inflorescence, seed weight per pods, seed weight per inflorescence and mean seed weight [45]. In oilseed crops oil is an essential component obtained from seeds. There are many factors that influence seed yield and seed quality such as genotype, agronomic techniques nutritional disorder and the environment. Seed quality is reflected in seedling density, seedling vigor, the competitiveness and uniformity of crop growth [46]. The quality of grains is basically depended on the storage proteins

present in their seeds. These proteins are mainly stored in seeds and came into existence at the time of seed development and acts as a nitrogen source during germination. [47] suggested that the polypeptide Polymorphic characteristics of storage protein is due to the existence of multigene families and this polymorphism can be seen within single genotypes as well as among genotypes of the same species.

The storage protein present in seeds ranging from ~10% (in cereals) to 40% (in certain legumes and oilseeds) of dry weight, are the fruitful source of dietary protein. Seeds comprised of one or more groups of proteins that are in abundance and acts as a store house for amino acids which can be use all along the seed germination and seedling growth. The total protein content present in seeds in the form of storage reserve determined the quality of seeds for various purposes [47]. Among several kinds of proteins four major types of storage proteins are known- globulins (insoluble in water), albumins (soluble in water), prolamins and glutelins, which are alcohol and alkali soluble respectively [48]. Globulins and albumins are the major storage seed proteins of legumes and oilseed crops whereas prolamins and glutelins are mostly found in cereal seeds. All four types of storage proteins are classified as simple globular proteins.

### 5.1 Albumins

Albumin proteins are mostly found in dicot seeds. These storage proteins are accumulated in the protein bodies of developing seeds and are serve as a source of sulfur-containing amino acids and carbon skeletons for providing nutrition to the growing seedlings and germination of the seeds. Despite of their physiological role, these small globular proteins in plants are also having an area of interest in the field of nutritional and clinical studies [49]. Agizzio *et al.* [50] have investigated that 2S albumins can also acts as defensive weapons for the protection against fungal invasion in plants. Arabidopsis and oilseed rape (family- Cruciferae) plants are most commonly used to study these proteins. In oilseed rape plants this protein is named as napins. Ericson *et al.* [51] suggested that the napins consist of two polypeptide chains with  $M_r$  values of -9000 and 4000, linked together with interchain disulfide bonds. The synthesis of napins gave rise a single precursor proteins in which proteolytic cleavage occurred. Due to this cleavage the loss of a linker peptide and short peptides from both the N and C termini was reported [51, 52]. All the 2 s albumins are compact globular proteins with conserved cysteine residues inspite of differing in their subunit structure and synthesis.

### 5.2 Globulin

Globulin storage proteins are found to be stored in the embryo and outer aleurone layer of the endosperm [53]. These proteins having sedimentation coefficients, approximately 7 and are found to be quickly dissolve in dilute salt solution. Kriz and Wallace [53] examined that the protein bodies are the main storage site for 7S globulins. The most primitive cupin superfamily is the representative of globulin proteins. On the basis of their sedimentation coefficients, they are of 11S legumin and 7S vicilin types. Globulins perform various functions such as sucrose binding, desiccation, defense against microbes, hormone binding and oxidative stress etc. in plant and also have nutritional values in seeds [54]. The functioning of globulin proteins in seed development was investigated by Hye-Jung Lee *et al.* [55]. According to their findings, deficiency in globulin induces the reduction in the expression of other seed storage proteins (glutelins and prolamins) in dry seeds of a rice mutant (Glb-RNAi) as compared to wild type. They also suggested that the

globulin might have a crucial role in a transcriptional mechanism and in the de novo protein maturation process of storage proteins in the rice endosperm.

### 5.3 Prolamins

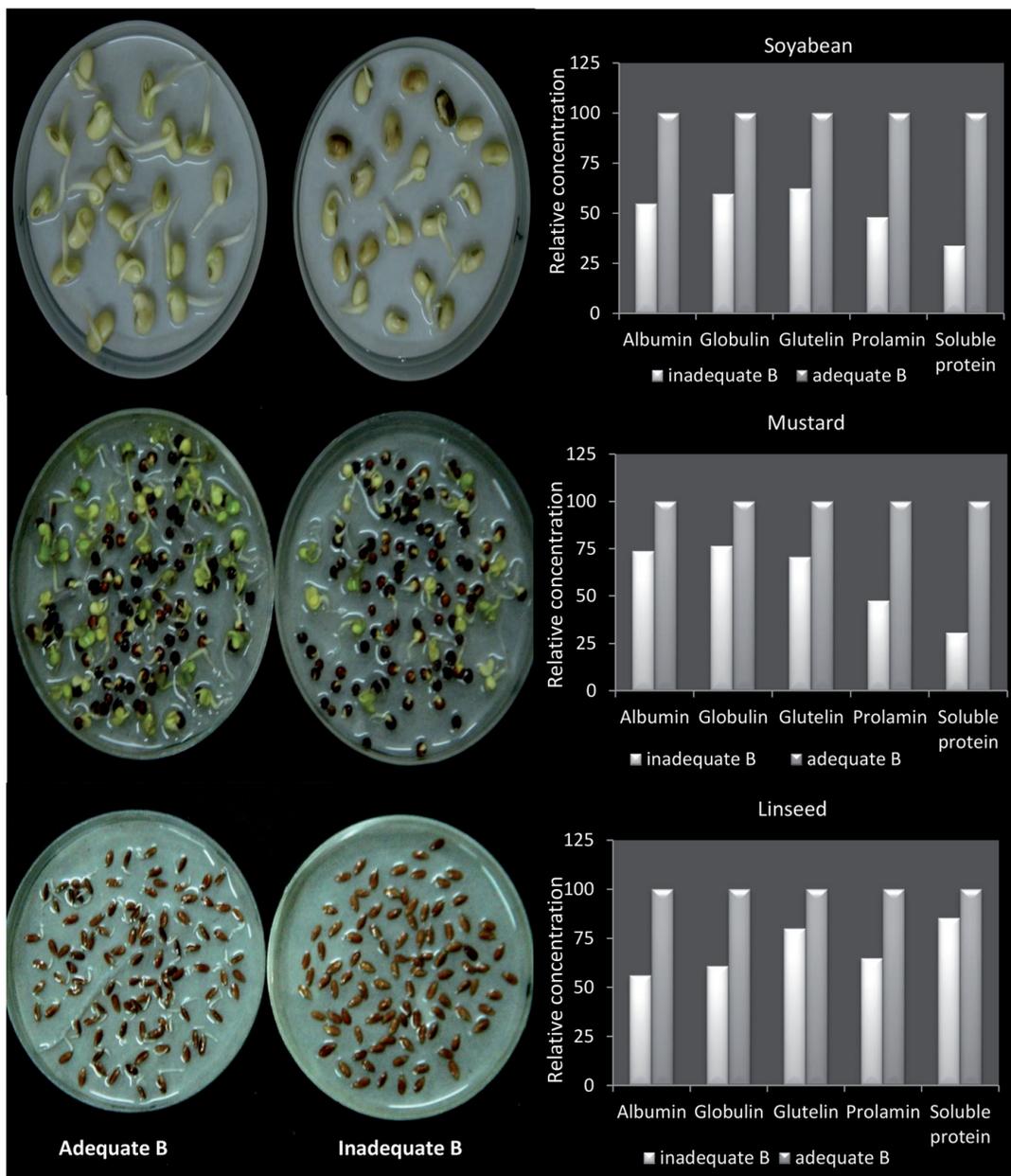
About 20% -30% seed protein is comprised of prolamins. Multigene family of 34 gene copies having relative molecular weights –10, 13, and 16 kD encoding the prolamin proteins. Among them the 13 kD molecular weight gene family comprises the major group. Further, on the basis of abundance of cysteine residues the 13 kD prolamins are classified in class I, II, or III, [56, 57]. Prolamins are the main storage proteins in the endosperm of all cereal grains. These proteins are basically rich in proline and amide nitrogen which is derivative of glutamine. The prolamins contains variable molecular masses ranging from approx 10 000 to 100 000. Miflin *et al.* [58], on the basis of amino acid sequencing, classified the prolamins into three groups namely S-rich, S-poor, and high molecular weight (HMW) prolamins. Among them S-rich prolamins are found to be about 80 to 90% of the total prolamin fractions consisting of monomeric and polymeric components with intrachain and interchain disulfide bonds respectively. The most abundant prolamin group among rice storage proteins is 13 kD prolamins that is indigestible in nature (Hyun-Jung [59]). Kim *et al.* [59] have generated transgenic rice plants (13 kD pro-RNAi) consisting of RNAi that are constructing against 13 kD prolamins. They reported in their results that 28% increase in the level of lysine, and abnormal formation of PB-I (protein bodies) in the transgenic grains might be due to the reduction in 13 kD prolamins at the mRNA and protein levels.

### 5.4 Glutelins

Glutelins are the member of the class of prolamin proteins. The seed endosperm of the grass family is mostly enriched with glutelin proteins. Gluten is the main component of the glutelin protein. Zhao *et al.* [60] established that about 70–80% glutelins are present mostly in rice. They also reported that glutelins are homologous to 11-12S globulin proteins of leguminous family. Wakasa *et al.*, [61] explained that the pre-proglutelins are the initial precursor of glutelins and due to hydrophobic interactions in the lumen of the rough endoplasmic reticulum they form homotrimers and heterotrimers. [62] reported the 15 glutelin genes in the rice genome, and classified them on the basis of their amino acid sequences into four groups- Glu A, Glu B, Glu C, and Glu D. Glu A consists of three members Glu A1, Glu A 2 and Glu A 3 and Glu B have four members Glu B1, Glu B2 Glu B3 Glu B4. Takahashi *et al.*, [63] demonstrated the localization pattern of five subtypes of the glutelin protein in rice grains with the help of glutelin-subtype specific antibodies. They reported that the localization of GluA was strongly in the outer region of the endosperm, including the subaleurone layer, and that of GluC was localized throughout the endosperm.

## 6. Impact of boron on seed germination and seed protein concentration

Post harvested seeds of all crops received boron inadequate nourishment were reduced in size and showed poor rate of germination (**Figure 2**). Seed germination was found to be retarded 37%, 36% and 43% in soyabean, mustard and linseed respectively. All the storage protein fractions- albumins, globulins, glutelins and prolamins were decreased in seeds of boron inadequate supplied plants as compared to plants supplied with appropriate amount of boron. In soyabean and mustard prolamins was found to be marked reduced as compared to other protein fractions



**Figure 2.**  
*Impact of boron on seed germination rate and seed storage protein concentration.*

and globulins (in mustard) and glutelins (in soyabean) are least effective. In linseed seeds albumins were found to be decreased more than other fractions and glutelins were least decreased. In soyabean seeds decrease in prolamins and soluble proteins ( $\approx 52\%$  and  $66\%$  respectively) were found to be more than albumins, globulins and glutelins ( $\approx 45\%$ ,  $40\%$  and  $38\%$  respectively). In mustard seeds also decrease in prolamins and soluble proteins ( $\approx 52\%$  and  $69\%$  respectively) were found to be more than albumins, globulins and glutelins ( $\approx 26\%$ ,  $23\%$  and  $29\%$  respectively). In linseed seeds decrease in glutelins, prolamins and soluble proteins ( $\approx 20\%$ ,  $35$  and  $14\%$  respectively) were found to be less than albumins and globulins and ( $\approx 44\%$  and  $39\%$  respectively) (**Figure 2**).

## 7. Conclusion

Inadequate boron nourishment may be a major factor responsible for low seed yield and quality of oil yielding crops widely cultivated on low boron soils world

over. Plants receiving inappropriate amount of boron nutrition showed decrease in all protein fractions. This might be due to increased activity of ribonuclease which disturbed the protein synthesis mechanism via influencing the RNA content of a cell. An increased ribonuclease activity in various crops under boron stressed condition was earlier observed by many workers [64, 65]. The observation made on the basis of results obtained in the present study suggested the role of boron in protein metabolism of seeds and that optimum concentration of boron is required for the appropriate synthesis of protein. Deformed seed structure and poor storage capacity for reserves might be the cause poor rate of seed germination. It is hoped that the information generated on the basis of this study will add to the information regarding the role of boron in seed protein reserve and quality improvement of seeds.

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