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Boron, the forgotten element

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ABSTRACT

Boron (B) is a trace element and a micromineral; it is a metalloid having qualities intermediate between those of a metal and a nonmetal, and it is found in the environment in many forms such as borates, boric acid, boric oxide, and sodium, calcium, and magnesium salts (Kabu and Akosman, 2013).Boron has also been utilised in a variety of sectors, it is a micronutrient with diverse and vitally important roles in metabolism that render it necessary for plant, animal, and human health. Boron is an essential element at low quantities but may be hazardous to plants and animals at greater amounts (Goldbach et al., 2007). It is also required for the function of various biological processes such as cell structure and enzyme activities, but it becomes toxic when boron levels in the aquatic environment become excessive (Ball et al., 2012).This study summarizes the effect of Boron on plants and animals and also it's toxic effect and it's anti toxic properties.

Boron Nature

Boron (B) is a trace element and a micromineral; it is a brittle, dark, lustrous metalloid (figure, 2) having qualities intermediate between those of a metal and a nonmetal, and it is found in many forms in the environment: such as boric acid, boric oxide, and sodium, calcium, and magnesium salts (Kabu and Akosman, 2013).

Boron is widely employed in glass manufacturing, as enzyme stabilizers in detergents, as a fertilizer in agricultural uses, and several industrial applications. B natural environmental inputs are related with borate weathering, although a number of sources that are caused by people, such as sewage effluents, coal combustion, cleaning agents, and agricultural chemicals, also raise B concentrations (Soucek et al., 2011). Boron has also been utilized in a variety of sectors, including ceramic materials, fibre glass, detergents, fertilizers, Preservatives for wood and many beauty products (Scialli et al. 2010).

Boron is a non-metallic element that occurs innately in more than 80 elements. Natural borate concentration in both surface and subterranean waters is typically low. Turkey contains more than 60% of the world's boron resources (Benzer, 2017).

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Boron Chemistry

Boron is the fifth element of the periodic table (Z=5), located in Group 13. It is classified as a metalloid due it its properties that reflect a combination of both metals and non-metals.

Boron is the only element in group 3 that is not a metal. It has properties that lie between metals and non-metals (semimetals). For example, Boron is a semiconductor unlike the rest of the group 13 elements. Chemically, it is closer to aluminum than any of the other group 13 elements.

Properties of Boron

Some chemical properties, along with the physical properties of boron, are mentioned in Table 1.

Boron and its Compounds

Many boron compounds are electron-deficient, meaning that they lack an octet of electrons around the central boron atom. This deficiency is what accounts for boron being a strong Lewis acid, in that it can accept protons (H^+ ions) in solution. Boron-hydrogen compounds are referred to as boron hydrides, or boranes.

Boranes

In the molecule BH_3, each of the 3 hydrogen atoms is bonded to the central boron atom. The boron atom has only six electrons in its outer shell, leading to an electron deficiency.

Table (1): Boron chemical and physical properties

Element Properties	
Atomic mass	10.811 g/mol
Electronic configuration	[He] $2s^2\ 2p^1$
Melting point	2349 K
Boiling point	4200 K
Heat of fusion	50.2 KJ/mol
Heat of Vaporization	480 KJ/mol
Specific heat capacity	11.087 J/mol.K
Oxidation states	+4,+3,+2,+1
Magnetic Ordering	diamagnetic
Electronegativity	2.04
Atomic Radius	90 pm
Stable Isotopes	^{10}B, ^{11}B

Diborane

This molecule has 12 valence shell electrons; 3 each from the B atoms, and 1 each from the six H atoms. To make this structure follow the rules required to draw any Lewis structure model, then it must have 14 valence shell electrons; however, it does not. The two B atoms and four H atoms lie in the same plane (sp^3- perpendicular to the plane of the page). In these four bonds 8 electrons are involved. Four electrons bond the remaining H atoms to the two B atoms and the B atoms together. This is done when the two H atoms simultaneously bond to the two B atoms. This creates what is called an atom "bridge" because there are two electrons shared among three atoms. These bonds are also called three-center two-electron bonds. The bond between the H and the B atoms can be rationalized using molecular orbital theory (Hassan, Heather, 2009)

Borax ($Na_2B_4O_710H_2O$) is the most common commercial form of boron. Boric acid (H_3BO_3) is the most common type of boron in aqueous solution at physiological pH. (Loewengart, 2001).

Isotopes and chemical shapes

Boron naturally contains two stable isotopes, ^{11}B (80.1%) and ^{10}B (19.9%) as shown in table (2), (3) and figure (1). The mass disparity leads in a broad range of ^{11}B values in natural waters, ranging from -16 to +59, according to (Vengosh et al.1994). Boron isotope separation is governed by the conversion processes of the boron species B $(OH)_3$ and B $(OH)_4$ (Schwarcz et al., 1969).

Occurrence of boron in nature

Boron that found in groundwater might be derived via the leaching of rural rocks, penetration of salts from meteors, blending with neighboring ground fluids, or pollution from man-made sources. While boric acid and borate minerals are broadly employed in applications in industry, boron compounds (particularly sodium perborate) are mostly used as a whitening agent in detergents. This consumption results in high boron levels in sewage all around the world.

Boron is melting at point of 2079°C, a boiling/sublimation point of 2550°C, a gravimetric of 2.34 in crystalline form, a specific gravity of 2.37 in amorphous form, and a valence of 3. Boron exhibits intriguing optical characteristics. Parts of infrared light are transmitted by the element boron. It is a weak electrical conductor at ambient temperature, but an excellent conductor at high temperatures. Boron could construct stable covalently linked molecular networks. Boron filaments are strong while being lightweight. Elements of boron have a greater energy band gap than silicon or germanium, ranging from 1.50 to 1.56 eV. Although elemental boron is not considered poisonous, boron compound absorption has a cumulative harmful impact, (From the Lange's Handbook of Chemistry, 1952).

Boron effects on animal and human

Boron (B) is the bio-element with the most remarkable speciation, with a very wide distribution within the principal three kingdoms of life (Archaea, Bacteria, and Eucaria) (Minchin et al., 2012).

Biochemical speciation is required for boron to be essential in plants and, more recently, in humans. Organic differentiations of boron is important for health of people because of its function in cellular metabolism in mammals. Within the 3 kingdoms of life there are a lot of esters of boric acid/borates exhibited as cis-diol biological molecules are known as active natural organic boron-containing compounds (BCCs), and examples include organic BCCs derived from plants and a few polyketide antibiotics (borophycin, boromycin, aplasmomycin, tartrolon B, C, and E),Complexes comprising boron siderophores (rhizoferrin, petrobactin, vibrioferrin, and aerobactin) with the bacterium signalling molecule AI-2 (furanosyl borate diester) (Donoiu et al.,2018).

Boric Acid (BA)/Borate (BX) is an inorganic BCC that found in soil which plants and microbes use to synthesise all known B organic natural chemicals (Prejac et al., 2018).

Table (2): Boron stable Isotopes

Isotope	Atomic mass (Da)	Isotopic abundance (amount fraction)
^{10}**B**	10.012 9369 (1)	[0.189, 0.204]
^{11}**B**	11.009 30517 (8)	[0.796, 0.811]

Atomic Weight of Boron". CIAAW. Retrieved 2021-10-26

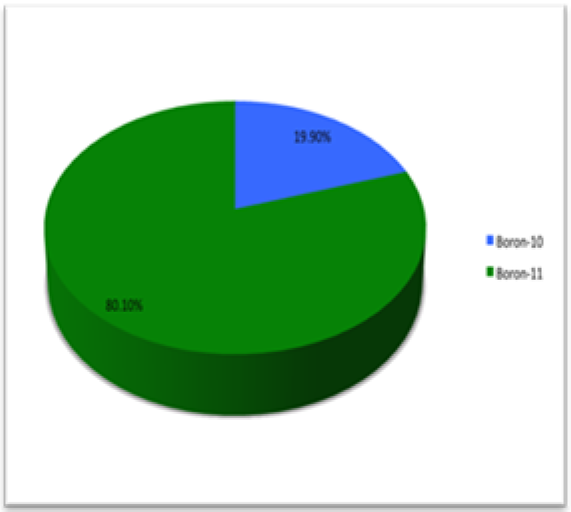

Figure (1): Boron stable isotopes

Figure (2): Boron

Boron might have beneficial effects on such functions as reproduction and development, calcium metabolism, bone formation, brain function, insulin and energy substrate metabolism, immunity, and the function of steroid hormones (including vitamin D and estrogen) (Hunter et al., 2019).

1- Biological role and importance of boron

Boron is an essential element at low quantities but may be hazardous to plants and animals at greater amounts (Goldbach et al., 2007).

Boron is a micronutrient that is needed for plants, animals, and people. It is also necessary for operations of many biological processes, such as the structure of cells and the activity of enzymes, but it turns toxic when the quantities of boron in the aquatic environment become excessive (Ball et al., 2012). It is also required for dietary and physiological processes, it plays a role in immune response, bone growth, both mineral and endocrine metabolisms, and it is a necessary dietary component for animals (Kabu and Akosman, 2013).

Boron is regarded as a bioactive trace element with beneficial properties. Boron appears to have a variety of impacts through regulating a signalling system in cell, the development and activity of an entity engaged in a variety of biological processes, and it is required for certain higher animals to complete their life cycles (Nielsen, 2014).

The proof that boron is a biologically active an important trace element is significant. Boron appears to have a wide range of impacts through affecting a cell signalling system or the development and/or activity of an entity engaged in numerous biochemical processes. It improves nutritional brain performance and the immunological or inflammatory response; it relieves or reduces the risk of joint inflammation; it enhances the action or usage of numerous hormones; and it is related with a lower risk of various malignancies. This implies that boron intakes above 1 mg/d may aid people "live longer and better" (Nielsen and Meacham, 2011; Nielsen, 2014).

a) Boron's importance to plants

Boron has been recognised for 75 years to be needed for vascular plant growth like radish (Raphanus sativum) root and apple (Malus pumila). Boron boosted the development of broad beans for the first time, according to Warington (1923).

Because of the lack of knowledge regarding B's precise and complementary functions, its significance in plant growth and development has recently received a lot of attention. Yet, important developments have proven that this element is crucial for terrestrial plants.

Boron plays a key role in plant metabolic activities. Its importance in the regulation of development of the root and shoot meristem is associated with plant developmental phase transitions, which are crucial processes in the completion of their life cycle. We provide further evidence that plants need to acquire sufficient amounts of B while protecting themselves from its toxic effects. Thus, the development of in vitro and in vivo approaches is required to accurately determine B levels, and subsequently, to define unambiguously the function of B in terrestrial plants (Pereira et al., 2021)

Kurt and Aydın (2020) identified and characterized five BOR1 transporters in potato (Solanum tuberosum) by using an in silico study. By performing an extensive co-expression network of each transporter, it was revealed that (i) there is a potential interaction between B transporters and genes involved in cell wall and (ii) a co-expression between StBOR1 transporters and plant immunity system.

Table (3): Boron isotopes (Meng et al., 2020)

Nuclide [n1]	Z	N	Isotope mass(Da) [n2][n3]	Half-life [resonance width]	Decay mode [n4]	Daughter isotope [n4]	Spin and parity[n6][n7]
	Excitation		**energy**				
^{7}B	5	2	7.029 712(27)	570(14) ys [801(20)keV]	P	^{6}Be[n8]	(3/2-)
^{8}B[n9]	5	3	8.0246073(11)	771.9(9) ms	$\beta^+\alpha$	^{4}He	2+
^{8m}B	10624(8) keV					0+	
^{9}B	5	4	9.0133296(10)		P	8Be[n10]	3/2-
^{10}B[n11]	5	5	10.012 936 862(16)	Stable			3+
^{11}B	5	6	11.009 305 167(13)	Stable			3/2-
^{11m}B	12 560(9) keV						1/2+(3/2+)
^{12}B	5	7	12.0143526(14)	20.20(2) ms	β^-(99.40(2)%)	^{12}C	1+
					$\beta^-\alpha$(0.60(2)%)	^{8}B[n12]	
^{13}B	5	8	13.0177800(11)	17.16(18) ms	β^-(99.734(36)%)	^{13}C	3/2-
					β^-n(0.266(36)%)	^{12}C	
^{14}B	5	9	14.025 404(23)		β^- (93.96(23)%)	^{14}C	2-
					β^-n (6.04(23)%)	^{13}C	
					β^-2n ?[n13]	^{12}C ?	
^{14m}B	17065(29)keV			4.15(1.90) zs	IT ?[n13]		0+
^{15}B	5	10	15.031 087(23)	10.18(35) ms	β^-n(98.7(1.0)%)	^{14}C	3/2-
					β^- (< 1.3%)	^{15}C	
					β^-2n (< 1.5%)	^{13}C	
^{16}B	5	11	16.039 841(26)	> 4.6 zs	n ?[n13]	^{15}B ?	0-
^{17}B[n14]	5	12	17.046 93(22)		β^-n (63(1)%)	^{16}C	(3/2-)
					β^-(21.1(2.4)%)	^{17}C	
					β^-2n (12(2)%)	^{15}C	
					β^-3n (3.5(7)%)	^{14}C	
					β^-4n (0.4(3)%)	^{13}C	
^{18}B	5	13	18.055 60(22)	< 26 ns	n	^{17}B	(2-)
^{19}B[n14]	5	14	19.064 17(56)	2.92(13) ms	β^-n (71(9)%)	18C	(3/2-)
					β^-2n (17(5) %)	17C	
					β^-3n (<9.1%)	16C	
					β^- (> 2.9%)	19C	
^{20}B[7]	5	15	20.074 51(59)	> 912.4 ys n	n	19B	(1-,2-)
^{21}B[7]	5	16	21.084 15(60)	> 760 ys	2n	19B	(3/2-)

b) Boron's Effects on Aquatic Animals

Boron enters the aquatic environment through a variety of pathways, including borate weathering, effluents of sewage, coal combustion, cleaning agents, and agricultural chemicals.

Aquatic creatures, such as fish, are extremely susceptible to borax exposure (Schoderboeck et al., 2011). It considers as a hazardous factor to aquatic creatures, and toxic concentrations vary greatly depending on species and test circumstances.

As a guide for evaluating the biological effect of boron, embryonic fish offer various benefits. Eggs may be fertilised in ultrapure water, do not require feeding, and can absorb boron and other important components from the water (Eddy and Talbot, 1985; Eckhert, 1998).

Rowe and Eckhert (1999) discovered that a high concentration of boron (45 mol/L) added to water enhanced the hatching rates of fertilised eggs compared to a level of boron of (0.1 mol/L) in water. They revealed a link between boron and the embryological development of zebrafish (*Danio rerio*); in short, their findings show that boron is required for early zebrafish development. The study identifies the most vulnerable phase as the time between fertilisation and blastulation. The first sign of a deficiency is membrane blebbing, which is followed by cytoplasm and yolk ejection. Boron is now proven to be vital in both zebrafish and plants.

Loewengart (2001) also said that the boron level in water must be greater than 0.03 mg boron L^{-1} to prevent boron deficit and to promote the progression of rainbow trout in both embryonic and larval stages.

Ardó et al. (2008) discovered that 0.05% boron in a mixture of Chinese herbs feeds (Astragalus membranaceus and Lonicera japonica) improved the immunological characteristics of Nile tilapia (*Oreochromis niloticus*) compared to the control.

Animal development and metabolism are affected by boron, and It was found that increasing the feed's boron content by 0.05% enhances growth parameters weight gain, final weight, condition factor, feed conversion, feed intake, specific growth rate, protein efficiency ratio, survival rates, economic conversion rate, and economic profit index of rainbow trout (*Oncorhynchus mykiss*). Elevated boron levels than this cannot improve rainbow trout development characteristics. Boron as a feed addition has been suggested to be advantageous for rainbow trout development (Oz et al.2018).

Boron's influence on Indian main carp was investigated by Adhikari and Mohanty (2012). (*Cirrhinus mrigala).* After 50 days of exposure, *C. mrigala* fry subjected to 0.50 mg B/L grew 33.3% faster than the control. They also discovered exposure to 1.0, 2.0, and 4.0 mg B/L had no influence on the fish's survival, growth, or feed intake. The growth acceleration at small levels (0.50 mg L^{-1}) of B might be attributed to its function in preserving strong cell membranes for proper cell function, as well as the fact that B enables different enzyme processes in the animal's body. In addition, B at 8.0 mg L $^{-1}$) lowered development by 52.4% and feed intake by 48.5% in *C. mrigala mrigala* was in comparison to controls. At higher B concentrations (8.00 mg L^{-1}), decreasing growth and feed intake may be induced by a toxic effect of B on fish brought on by a disruption of normal physiological processes. If B's quantities are higher than what is physiologically necessary, it may function as an enzyme inhibitor, which could have harmful effects or stunt growth.

Oz et al. (2021) studied the impact of boric acid on rainbow trout (*Oncorhynchus mykiss*) development and nutritional composition. Boric acid was given to rainbow trout (*Oncorhynchus mykiss*) diet at concentrations of 0.00%, 0.01%, 0.05%, 0.10%, and 0.20%. The feeding duration lasted 90 days, and they discovered that the group with 0.05% of boric acid had the highest growth performance, while the group with 0.20% of boric acid had the lowest.

According to the findings of this work, it was determined that the presence of up to 0.05% of boric acid in fish feed had a favourable effects. They wanted to know if adding boric to fish feed would cause rainbow trout to reach market size sooner or acquire more live weight in the same period.

There are two primary causes for the favourable benefits of impacted growth with boron supplementation.

The first explanation is because boron is involved in the cell membranes transfer (Takano et al. 2008). For cell development and proliferation, the boron transporter NaBC1 in the cell membrane acts as an electrogenic Na^{+-} coupled borate transporter. (Park et al. 2004). This transporter is linked to the cell membrane's integrity and health (Park et al. 2005). There is a cell division on the cell membrane, which is primarily in charge of an organism's development and may be the primary explanation for boron's growth stimulating action.

The second explanation is that boron is involved in the routes of many enzymatic activities in mammalian metabolism (Adhikari and Mohanty 2012). Animal metabolism's use boron molecules in protection against the growth and lowering of triglyceride levels in blood, Specifically, non-esterified fatty acids, total cholesterol, insulin, and low-density lipoprotein (Kabu and Civelek 2012). Furthermore, boron participates in oxidative stress-reducing systems like the glucose-alanine cycle and methionine metabolism, and it has a favourable effect on the lipid profile (Basoglu et al. 2011).

Acar et al. (2018) investigated the impact of boron on DNA fragmentation in Nile tilapia blood and sperm cells (*Oreochromis niloticus*). They treated Nile tilapia with five elevated B concentrations (1, 5, 25, 50, and 100 mg L-1B and haematological and biochemical B), measured haematological, serum biochemical parameters, and DNA damages in these treatments compared to the control after 14 days of exposure, and discovered that boron caused DNA fragmentation in blood and sperm cells of Nile tilapia.

2- Pathway and Metabolism of Boron in animal and human body

Boron does not accumulate in most body tissues, but bone, nails, and hair have higher boron levels than other body tissues, whereas fat has lower levels (Uluisik et al.,2018) Boric acid is the main form of boron in blood, urine, and other body fluids (Eckhert., 2014). The lack of substantial changes in blood boron levels in response to large increases in dietary intakes suggests that the body maintains boron homeostasis, likely by increasing urinary excretion, but the regulatory mechanisms for boron homeostasis have not been identified. Boron is excreted mainly in the urine, and small amounts are excreted in the feces, sweat, breath, and bile (Khaliq et al., 2018).

3- Boron Toxicity

Oz et al. (2020) investigated histopathological alterations in rainbow trout (*Onchorhyncus mykiss*) fish have fed with feed supplied by boric acid. They added boric acid (BA) to feed (0.01%, 0.05%, 0.10%, and 0.20% of B in feed) and compared the impact on four treatments to the control. They observed lamellar edema, degenerative changes, inflammatory cell infiltrations in and severe lesion in gills. Hydropic and vacuolar degeneration in hepatocytes in the liver were slight to severe, also mononuclear cell infiltrations, biliary hyperplasia in portal areas and necrotic changes in hepatocytes were observed.

Capkin et al. (2017) investigated the Histopathologic and genotoxic consequences of Borax on rainbow trout and found a substantial histopathologic damage in gill, spleen, liver, and fish kidney tissue subjected to low levels of Borax. After a chronic exposure of BRX, the kidney is the most impacted organ. Except for Catalase, all the genes tested were managed. The most impacted gene was HSP 90 BA, which rose by 2129.69-fold, while the least affected gene was CAT, which was unorganised.

According to Topal et al. (2016), histopathological effects of acute exposure to boric acid concentrations in rainbow trout were identified, BA concentrations of 102 and 103 mg/L were administered to the fish. Histological abnormalities were observed in rainbow trout gill, kidney, and muscle tissues following acute exposure to boric acid.

Gülsoy et al. (2015) studied the borax (BX) and boric acid (BA) potential pathways on the genotoxicity of zebrafish (*Danio rerio*) for acute exposures lasting 24, 48, 72, and 96 hours (levels: 1, 4, 16, and 64 mg/l BA & BX). Genotoxicity was found to be concentration-dependent for BA and time-dependent for BX. In general, experimental groups showed substantial impacts (P 0, 05) on concentrations and exposure durations too. DNA damage was greatest at 96 hrs and 24 hrs for all BX and BA levels in *D. rerio* peripheral blood. They discovered that specimens exposed to all concentrations of BA and BX exhibited a substantial raise in DNA damage when in comparison with the negative control. The Comet test may identify DNA strand breakage caused by boric acid and borax, independent of dose or time, in fish in the aquatic environment, particularly near boron-rich locations. Sensitivity to boron compounds is prevalent in organisms.

Inanna and Yilmaz (2018) studied the effects of food-borne and water-born of boric acid on fish sperm movement, sperm samples were cryopreserved in liquid nitrogen to ascertain how cryopreserved samples differ in quality. The study employed that each treatment has 12 adult male's goldfish (*Carassius auratus*), which was randomly separated in triplicate for 45 days. For food-borne tests, fish have consumed food containing 1 mg, 5 mg, and 10 mg of B/kg feed. Fish were stocked in aquariums with 1 mg/L, 10 mg/L, and 20 mg/L of B in water-borne studies. In fresh samples, the percentages of sperm movement and feasibility decreased in comparison to the control, B concentrations were higher in both B treatments.

4) Boron's anti-toxicity properties

Boron's biological effects on living beings are well-defined, including cyto-protection and geno-protection.

Yeltekin et al. (2022) investigated the protective effect of Borax against ferrocene-induced neurotoxicity in Oncorhynchus mykiss.result showed FcH caused inhibition in enzyme activities(catalase (CAT), glutathione peroxidase(GPx), su peroxide dismutase (SOD) And it was observed that BX has a mitigating effect on FcH-induced neurotoxicity.

Alak et al. (2019) investigated the impact of borax (BX) against exposure to heavy metals in vivo transcriptional and physiological processes, as well as their effect on rainbow trout gill and liver tissues and discovered that when compared to the copper combination group, levels of 8-OHdG, Caspase-3, and malondialdehyde were lower while antioxidant enzyme activity was higher. Under oxidative stress situations, it is hypothesised that borax stimulates an antioxidant as a defence system and performs a highly protective function in tissues, cleaning detoxification processes and free radicals, keeping cells' structural integrity intact and organelles; they also offered an outline of the BX's strategic therapeutic potential in rainbow trout, *Oncorhynchus mykiss*. For 21 days, fish were given varying dosages of BX and/or copper (1.25, 2.5, and 5 mg/kg BX; 500 and 1000 mg/kg Cu) in both pre-treatment and combination alternative treatment. The haematological index (total erythrocytes count (RBCs), total leucocytes count (WBCs), haemoglobin (Hb), hematocrit (Hct), total platelet count (PLTs), mean cell haemoglobin (MCH), mean cell haemoglobin level (MCHC), mean cell volume (MCV)) and nuclear deformations in blood specimens of treated and untreated fish were evaluated at the end of the treatments (pre and combined). After Cu exposure, Fish from both treated and untreated groups showed statistically significant (p ≤0.05) and dose-dependent increases in haematological indices, 8-OH-dG levels, and rates of nuclear deformations. Treatments with BX dosages alone, on the other hand, had no effect on these haematological and DNA damage endpoints. Furthermore, both pre-treatment and combination BX treatments greatly reduced Cu-induced hemato-toxicity and genotoxicity. Finally, the results showed that borax has hemato-protective and geno-protective effects against copper-induced toxicity in fish.

Ali et al. (2019) investigated the antifungal properties of boron. Saprolegniosis is a fungal-like disease that affects freshwater fishes and their eggs all over the world. They evaluated the efficacy of boric acid (BA) to shield Nile tilapia (*Oreochromis niloticus*) from contracting Saprolegnia based on reports of significant deaths and associated financial losses brought on by Saprolegnia infections. In vitro, BA reduced the radial development of Saprolegnia hyphae. When Nile tilapia (*Oreochromis niloticus*) were experimentally defied with Saprolegnia, disincentive effects were also detected in vivo. Spores had been tracked for 10 days after the challenge, with continuous exposure to various BA concentrations. There were no symptoms of saprolegniosis in fish treated with BA at concentrations of 0.4 g/L and higher. BA-treated fish showed no significant histomorphological alterations as compared to non-treated controls.

Alak et al (2018) investigative the protective effect of Borax Supplementation to Hematotoxicity and DNA Damage in Rainbow Trout (Oncorhynchus mykiss) exposed to copper. Fish were fed with different doses of BX and/or copper (1.25, 2.5, and 5 mg/kg of BX; 500 and 1000 mg/kg of Cu) for 21 days in pretreatment and combined treatment options. At the end of the treatments (pre and combined), the hematological index (total erythrocytes count (RBC), total leucocytes count (WBC), hemoglobin (Hb), hematocrit (Hct), total platelet count (PLT), mean cell hemoglobin concentration (MCHC), mean cell hemoglobin (MCH), mean cell volume (MCV)), oxidative DNA damage (8-hydroxy-2-deoxyguanosine (8-OHdG)), and nuclear abnormalities in blood samples of treated and untreated fish were investigated. The statistically significant ($p < 0.05$) and dose-dependent increases in hematological indices, 8-OH-dG level, and rates of nuclear abnormalities were observed after exposure to Cu in both treatment group fish as compared to untreated group. On the contrary, treatments with BX doses alone did not alter these hematological and DNA damage endpoints. Moreover, both pretreatment and combined treatments with BX significantly alleviated Cu-induced hematotoxicity and genotoxicity. In a conclusion, the obtained data firstly revealed that borax exhibited hematoprotective and genoprotective effects against copper-induced toxicity in fish.

Ince et al. (2014) studied the protective effects of boron on cyclophosphamide induced lipid peroxidation and genotoxicity in rats. They revealed that SOD and CAT activity in liver decreased compared to control. Totally, thirty Wistar albino male rats were fed standard rodent diet and divided into 5 equal groups: physiological saline was given intraperitoneally (i.p.) to the control group (vehicle treated), to the second group only 75 mg kg^{-1} CYC was given i.p. on the 14th d, and boron was administered (5, 10, and 20 mg kg^{-1}, i.p.) to the other groups for 14 d and CYC (75 mg kg^{-1}, i.p.) on the 14th d. CYC caused increase of malondialdehyde and decrease of glutathione levels, decrease of superoxide dismutase activities in erythrocyte and tissues, decrease of erythrocyte, heart, lung, and brain catalase, and plasma antioxidant activities. Also, CYC treatment caused to DNA damage in mononuclear leukocytes. Moreover, B exhibited protective action against the CYC-induced histopathological changes in tissues. However, treatment of B decreased severity of CYC-induced lipid peroxidation and genotoxicity on tissues. In conclusion, B has ameliorative effects against CYC-induced lipid peroxidation and genotoxicity by enhancing antioxidant defence mechanism in rat.

Conclusions

It has been established that boron is a crucial trace mineral. It is important for growth in plants, animals and human, reducing the toxic effect of heavy metals and raises the level of antioxidant enzymes such as SOD, GPX and CAT.it also have cyto-protection and geno-protection role.as any element Boron have a toxic effect in excessive amount.

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