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Role of Moringa, Brassica and Sorghum Water Extracts in Increasing Crops Growth and Yield: A Review

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Abstract: Allelopathic water extracts are the substances that are prepared from the allelopathic crops like Brassica and sorghum and applied in small concentrations as foliar sprays to increase the growth and yield of a range of crops. Sorghum water extract is known as sorgaab that can inhibit the growth and infestation of weeds when applied in combination with low doses of herbicides. Moringa leaf juice is rich with numerous growth hormones, particularly zeatin that has been reported to increase the crops yield in the range of 10-45%. Moringa leaf juice also contains micronutrients in sufficient quantities and suitable proportions that increase the growth, yield components and yield of a variety of crops ranging from cereals to oil seed crops, from fibrous to sugar crops and from forages to tuber crops.

Key words: Allelochemicals · Allelopathy · Brassinolide · Sorgaab · Zeatin

INTRODUCTION

Allelopathy is the name of interaction between plants species in which plants are affected by other plants, positively or negatively due the release of certain secondary plant metabolites, called allelochemicals [1]. The results of allelochemical action can be traced at various levels of plant vital processes. Enzyme activation, enhanced cell division, more membrane permeability, increased ion uptake and increased plant growth and development are direct actions allelochemicals [2]. Among different natural sources of PGRs, Moringa leaves have attained a prominent position among the scientific community because its leaves contain a substance known as zeatin [3]. This substance can be used as a source of cytokinin. Moringa is the sole genus of *Moringaceae* family. *Moringa oleifera* L. is widely distributed in the Pacific region [4], sub- tropical regions [5] and in West Africa [6]. The charisma of Moringa leaf juice is a substance: zeatin which is natural plant hormone. It has been established that leaves of Moringa are rich in natural cytokinin along with other minerals, phytohormones and inorganic salts that are in a naturally balanced concentration which increase the yield of the crops when applied exogenously. A score of related compounds are found in a variety of plants called brassinosteriods [7]. Brassica water extracts contain a substance known as brassinolide which is natural plant steroid. The brassinosteroids are included in a unique class of natural plant growth regulators having the potential to enhance yield of number of agronomic crops. They were originally discovered simultaneously in Japan and America, in "Isunoki," which is an evergreen tree and in pollen of canola (*Brassica napus* L.) [8]. Brassinolides are natural plant hormones that promote vegetative growth, enhance yields of grain crops as well as fruit crops while increase the plant potential to withstand drought and cold weather more effectively and efficiently [9]. Plants that cannot synthesize these substances become dwarf, thus are essential for normal growth and development of the plants.

Moringa Leaf Juice Allelopathy: Along with other plant requirements such as water, macro and micro nutrients, there are certain plant growth regulators and hormones that have the ability to increase the yield by influencing the plant internal processes. This fact was demonstrated in a detailed research in which Price [10] reported that Juice from fresh Moringa leaves were used to produce a good and effective plant growth hormone and reported that this hormone increased yields by

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25-30% in a variety of crops including maize, onions, soyabean, sorghum, coffee and melon. It was later discovered that it was actually zeatin that is a natural plant hormone and belongs to the cytokinine group, involved in increasing the yield of crops. It was suggested that zeatin foliar spray should be applied along with other fertilizers, making it clear that this hormone cannot serve in place of fertilizers but if applied along with other fertilizers produce better results. With this experiment, importance of Moringa leaf juice as a natural plant growth promoter came into light. Same were the results presented by Fuglie [11] that leaf extracts of *M. oleifera* accelerated growth of young plants, strengthened plants as a whole, improved plants resistance to pests and diseases, increased leaf area duration, increased number of roots, produced more and larger fruits and generally increased yield by 20 to 35%. He conducted field trials and applied the Moringa leaf juice as a foliar spray and found that all the growth parameters were positively influenced by the spray and in the end it was observed that total yield was increased by 20%-35%.

This natural plant hormone has the potential to increase the yield of number of agronomic crops even when applied in small concentration. This fact was revealed by Foidle [12], who reported that when foliar spray was applied on the leaves of plants with the Moringa leaf extract that was prepared in 80% ethanol and then was diluted with water almost ten times produced some notable effects. It was reported in the end that this foliar spray of Moringa water extracts enhanced the yield significantly despite the fact that it was applied in very minute amounts. This research indicated that Moringa leaf juice contain substances that promoted the vegetative growth and grain yield of many crops. Seed and soil-borne diseases especially of fungal origin reduce the yield of crops and in some cases result in the complete destruction and failure of crops. Moringa leaf juice increased the yield of crops but Akinbode and Ikuton [13] even went a step ahead and explored the antifungal characteristics of Moringa leaf juice. They applied in their research, Moringa leaf extracts along with other plant extracts on seeds of cowpea and found that Moringa leaf extracts inhibited the attack of seed born fungal pathogens more significantly as compared to other plant water extracts. In this way antifungal characteristics of Moringa leaf extracts came into light and open new horizons for Moringa leaf juice use as an antifungal agent. After the determination of growth promoting properties of Moringa leaf juice, next step was to determine the optimum concentration of Moringa leaf juice. With this vision, Phiri [14] applied *Moringa oleifera* leaf extracts in the ratio of 1:10 (w/v) on seeds of maize, rice, sorghum and wheat in a growth room at 25°C for 14 days and found that it not only increased the length of radical but also increased hypocotyl length of maize and wheat. It was reported that this hormone application as a seed treatment not only improved the vegetative growth but also enhanced the grain yield even applied in very small amounts as a seed treatment. To verify the results of zeatin, Phiri and Mbewe [15] conducted another series of experiments in which Moringa (*Moringa oleifera* L.) leaf extracts were applied on seeds of three legumes including beans, groundnut and cowpea and found that extract obtained from Moringa when applied in small concentration reduced time of germination. It was reported in the end that this Moringa juice extracts also increased the length of hypocotyls of groundnut.

Zeatin obtained from Moringa leaf juice is effective and yields positive results in a variety of crops. Makkar and Becker [16] found that the juice from fresh Moringa leaves can be used to produce an effective plant growth hormone, increasing yields by 25%-30% for a number of crops such as soybean, maize and coffee. Field trials were conducted on a number of agronomic crops and were sprayed with the juice extracted from the leaves of Moringa. In the end it was found that Moringa leaf juice increased the yield of all crops tested, by 25%-30%. After becoming aware of zeatin growth promoting character, scientists diverted their attention towards mineral composition of Moringa leaves in order to discover that either any other type of hormone is promoting the growth of plants along with zeatin. Anjorin *et al.* [17] studied the mineral composition of the lamina, petiole, seed pod and seed kernel oil of Moringa *oleifera* L. from two regions, Sheda and Kuje, Abuja, Nigeria in order to investigate the types of minerals and their composition. The results indicated that Ca, Mg, Fe and Cu in *M. oleifera* leaves, pods and seeds from Sheda were relatively higher than that from Kuje. Relatively high contents of calcium and iron were found in the lamina and seed shell of the plant respectively from both regions. The Mg content in the seed kernel oil of Moringa from Sheda was significantly lower. It was also discovered that phosphorous was less than or equal to 0.05 ppm. The iron content in the seed shell from Sheda was 0.2436 mg g^{-1} more than those from Kuje. It was found that toxic element such as Pb was absent in the leaves, pods and seeds of Moringa from

both locations. This study confirmed the presence of various macro as well micro elements and also proved the fact that there are variations in macro and trace minerals in Moringa leaves, pods and seeds from different locations.

Ella *et al.* [18] carried out a research to determine the effects of preculture in abscisic acid and exogenously zeatin was applied and their affects were studied regeneration of the plant from calli of rice. It was found that abscisic acid increased regeneration in the medium that was zeatin-free. The importance of zeatin lies in the fact that deficiency of zeatin, sets in the senescence. The deficiency was produced because of more zeatin transportation toward the roots. This fact was further verified by Ambler *et al.* [19], who did a novel study by testing the xylem sap from decapitated vegetative and mature plants of non-senescent and senescent sorghum (*Sorghum bicolor* L.) and analyzed them in order to check the concentration of cytokinins so as to determine whether the delayed leaf senescence of nonsenescent sorghums was linked to transport of greater quantities of cytokinins towards the roots. For field-grown plants, the amount of zeatin riboside (ZR) in xylem sap per gram shoot dry weight was 1.51 times higher for the non-senescent sorghum as compared to senescent plants. He made conclusion that higher concentration of zeatin was moved to roots that caused senescence. Jee *et al.* [20] carried out experiments to optimize the composition of plant growth regulators which affected protoplast cultures and plant regeneration vigor of the mesophyll protoplasts in the *Brassica oleracea* L. Numerous plant growth regulators were applied and in the end it was revealed that zeatin in the amount of 4mg/L produced the best results by increasing the growth of plants grown in medium. Another characteristic of zeatin for enabling the plants to withstand the periods of high temperature with more vigor and efficiency was revealed by Cheikh et al. [21], who studied the maize kernel distortion which was the result of high temperature. They studied the effect of high temperature on seed kernel distortion while keeping a control treatment and in the end it was revealed that temperature stressed maize kernels have a higher concentration of zeatin than those grown at normal temperatures. Thus they revealed the fact that shifts in hormone balance of kernels is one mechanism by which plants manage the high temperature by producing more zeatin. Lee et al. [22] conducted experiment to determine the effect of various cytokinins on the growth and development of callus of sesame. Results showed that cytokinins at high concentration inhibited the root development of sesame but enhanced the green part formation even at higher concentraton. Zeatin was the most effective among cytokinins that were tested, but shoot was not formed from the callus on any regeneration. Al-Hussain *et al.* [23] applied zeatin in very small concentration on plants in medium along with one treatment of incubation for 1-2 weeks and on another treatment immediate light exposure was given. Results showed that incubation of 1-2 weeks gave better results while concentration of zeatin was of no matter. Okuse *et al.* [24] studied the effect of different cytokinins on shoot regeneration from leaf explant of common cabbage (*Brassica oleracea* L.) and found that all cytokinins were effective in promoting the regeneration of plant from explant. As far as the concentration of zeatin is concerned it was found that the concentration of zeatin was broader than that of any other cytokinins. The studies have revealed the process and mechanism by which zeatin promotes the growth of plant by stating that zeatin is present in more concentrations in parts of plant where more growth and cell division occurs. Polivoj and Polevoj [25] conducted a research to find the concentrations of endogenously applied phytohormones in different organs of maize seedlings. From this study in particular, it was established that tissues with high meristematic activity such as root tip were characterized by a high cytokinin (zeatin & zeatin riboside). Zeatin is also involved in carbohydrates mobilization as well as distribution to the sink where more carbohydrates are needed to cater the needs of rapidly increasing growth. This was proved by Munoz *et al.* [26], who conducted experiment to investigate the effects of cytokinins in carbohydrate and protein mobilization in *Cicer arietinum* L. They reached to the conclusion that Zeatin riboside affected mainly the mobilization of carbohydrates and has less effect on protein mobilization. Zeatin on combining with carbohydrates increases growth. In most recent studies some scientists such as Kato *et al.* [27] have revealed the fact by conducting an experiment in which they found that on combining the zeatin with glucose produces a compound called the Zeatin-o-glucoside (GOS). This compound had the highest growth promoting activity even 100 times more than that of zeatin and zeatin riboside and played a vital role in shoot greening of cucumber. These results suggested that in some developmental stages, the combination of cytokinins with a carbohydrate, such as glucose, was a key factor in controling the shoot greening by roots. Lashari *et al.* [28]

conducted an experiment to optimize the zeatin concentration and in the end suggested that Optimum zeatin concentration for cotton was 0.5-25 muM that yielded the best results as compared to other higher concentrations. Zeatin plays a vital role in keeping the plants green for a longer period of time. This was established by Seojima *et al.* [29], who investigated the root exudates of different rice cultivars and from the data it was revealed that plants exudates containing greater amounts of cytokinins especially zeatin remained green longer than other ones [30] and from this research it was also revealed that there is a relationship between the senescence and zeatin concentration [31]. Senescence was delayed in plants having more zeatin concentration.

Brassica Water Extracts Allelopathy: Brassica water extracts promote the growth of variety of agronomic crops by affecting different physiological processes of the plants. The charisma of Brassica water extracts is a natural hormone known as brasinolide. Anjum [32] found in his study that brasinolides obtained from Brassica species when applied on the maize crop in early growth stages improved the drought tolerance of the crop and improved the ability of the crop to withstand the drought period more efficiently. He came to the conclusions that brasinolides induce more tolerance in plants to withstand the drought period and too in an efficient manner and give more yields as compared to plants that were not sprayed with these compounds. Brassinolide enhances the growth and development of the plants and ultimately the yield if it is applied at early stages of plant growth. Jeyakumar *et al*. [33] reported in his research that foliar application of brasinolide at the pre-flowering stage increased plant height, number of branches and leaf area index and leaf area duration of the black gram. It was also reported that photosynthetic efficiency was greatest in plants treated with brassinolide due to which more carbohydrates were produced and ultimately greater leaf weight, chlorophyll content as well as more soluble protein contents were produced. Brassinolide has the potential to make plants more resistant to low temperature as proved by Kim [34], who conducted a research to explore the effect of brassinolide, on the rice seedling under low temperature ranges. Various concentrations of brassinolide were applied on the seed, as well seedlings of rice. Plant height was increased to large extent when seeds were soaked in 1 ppm brassinolide solution, it was found that emergence of leaves was accelerated by brassinolide application. Brassinolide, if applied as a foliar spray increases plant height of almost all the crops. This fact was established by Sasse [35], who conducted a field trial to evaluate the promotive effects of brassinosteroids on the elongation of dwarf pea and cucumber. It was reported that there is a synergism between brassinolide and auxin in order to induce elongation when it is ineffective alone. Exogenous auxin affects the mechanism of the response to brassinolide. Mayumi *et al*. [36] found in an exhaustive research that brassinolide, enhanced the elongation of epicotyl of the bean seedlings that was induced by IAA and hence it was taken for sure that brassinolide enhanced the vegetative growth of bean despite the fact it was applied in a very small concentration. Another characteristic of brassinolide came into light when Choi *et al*. [37] conducted a research to investigate the safening effect of a natural plant growth regulator brassinolide against herbicides, 2, 4-D and butachlor. Seeds were soaked in brassinolide at 1ppm concentration and it was observed that it was effective in reducing the herbicidal phytotoxicity of rice seedling on 2, 4-D and butachlor application. The safening effect of 2, 4-D by brassinolide was more visible at low concentration as compared to high concentration of brassinolide. Anuradha [38] reported after carrying a detailed study in field that when the seeds were treated with brassinolide solution having concentration more than 10 ppm delayed the germination process and also reduced the germination in tobacco seed which means only those seeds treated with low concentration of the brassinolide enhanced the germination. It was also concluded that foliar spray of brassinolide had no effect on tobacco growth as well as tobacco quality and yield when treated with more than 10 ppm brassinolide solution. Xu *et al*. [39] reported that brassinolide increased survival rate of *Pinus bungeana* seedlings in case of higher cold by 14.5%. The reason and mechanism involved in creating the resistance in plant against the cold was found to be due to effect of brassinolide on plasma lemma. Hao [40] conducted a field research and reported that ripening process of tomatoes could be fastened significantly by applying 1 ppm of brassinolide or 1000 ppm of ethrel onto plants at pre-harvest stage. It was recorded that the yield of the earlier stage was increased and the total yield was not affected notably. It was also reported by the same study that the higher quality fruits were produced when treated with brassinolide as compared to those treated with ethrel. Seeds when treated with brassinolide give more vigorous growth and healthy seedling. This fact was revealed by Jones *et al*. [41], who came to a conclusion in an

exhaustive research in which brassinosteroids accelerated plant growth when applied to seeds. The effects of cress seed treated with brassinolide. Very small concentration of brassinolide was applied to the seeds of cress and it was recorded that it improved the germination but higher concentration of brassinolide inhibited the root germination of cress seeds. Terakado *et al*. [42] used in their study, a most effective natural plant hormone brassinosteroids along with brassinazole which is an effective inhibitor of brassinosteroid. It was observed that foliar application or direct injection of brassinolide into the root promoted nodule formation. They reported that the internodes in the plants treated with the brassinolide were more as compared to non- treated ones. It was also observed that brasinolide application resulted in more nodes formation. Anuradha [43] studied the effect of brassinolide on germination and seedling growth of rice (*Oryza sativa* L.) under salinity conditions and came to conclusion that brassinolide inhibited the reverse effects of salinity on germination and seedling growth. This reverse effect produced by the brassinolde was due to higher levels of nucleic acids, soluble proteins and free proline and in this way the ability of brassinolide to reverse the effects of salinity on germination of seeds came to light. Clouse and Zurek [44] conducted experiments to study the effect brassinolide on the tumor cells of tobacco and found that brassinosteroids significantly inhibited tumor cell growth in tobacco plant and results were more pronounced in case of lower concentration of applied brassinolide. Upreti [45] conducted research and found that epibrassinolide or homobrassinolide enhanced root nodulation and root length of *Phaseolus vulgaris*. It was also reported that brassinosteroids treatment (5 mm) increased pod yield and this yield was even higher in well irrigated plots. This characteristic of brassinolide of improving the growth and yields was further demonstrated in a research in which Andrzej [46] found that brassinosteroids are found in a wide range of organisms including lower and higher plants. These hormones had the potential to make the plants more capable to withstand the abiotic stress in an efficient manner. Brassinolides are involved in making the plants more resistant to salt stress as described by Qayyum [47], who conducted an experiment and in the end found brassinolide enhanced the growth, chlorophyll pigments of rice plants and it was also recorded that gas exchange rates were higher in brassnolide treated plants as compared to other plant even in salinity dominant conditions.

Han and Kairong [48] discovered another novel characteristic of brassinolide in an experiment that it produced water stress resistance in plants of *Hippophae rhamnoides* L. and *Amorpha fruticosa* L. Results revealed that plants treated with 0.2-0.4 mg/ L of brassinolide showed more leaf water contents. It was observed that short and minute deficiency of water was compensated by brassinolide. Kwak *et al*. [49] observed the effects of brassinolide on seedling characteristics of rice under low temperature condition. Results showed that plant height was increased when 1 ppm brassinolide was applied to seeds and seedlings. Root length was increased but the number of roots plant^{-1} was increased only when seeds were treated with 1 ppm of brassinolde. Dry weight of shoot and root was also increased by application of brassinolide. Brassinolide has the potential to reduce the germination time as observed by Takeuchi *et al*. [50], who discovered the effect of brassinolide in reducing the germination time, as well as its ability to counter the inhibitory effects on the germination produced by various toxic substances. Witch weed (*Striga asiatica* L.) was treated with brassinolde and results demonstrated the fact that it not only reduced the germination time but also reversed the mechanism by which inhibitory substances come into being. Fujji *et al*. [51] adopted rice for their experiment and in the end gave the results that brassinolide increased the grain weight of rice and the ripening process of grains in rice plants. In another novel study carried out by Cai *et al*. [52] in which they applied the brassinolide on canola plants from which these were first ever discovered. In the end it was observed that when brassinolides applied in small concentration as small as 0.1 ppm plant^{-1} increased the hypocotyls length of the *Brassica napus* plants. Role of brassinolides in maintaining the proper vegetative growth particularly the height of the plant was revealed in a novel study carried out by Numora *et al*. [53], who determined the level of exogenously applied brassinolide in the dwarf mutant of garden pea and normal plants. They found that the level of brassinolide was quite low in dwarf plants than in the normal ones.

Honda *et al*. [54] carried out a research in order to investigate the response of barley to the application of exogenous brassinolides and came to the conclusion that some dwarf plants of barley were non-responsive to a large extent to the exogenous application of growth promoting brassinolides and hence their dwarfism was attributed to non-retention of brassinolides and on the other hand normal plants showed the best response to the

exogenous application of brassinolides and hence their vegetative as well as grain yield was increased significantly. There is no other opinion in growth promoting activity of brassinolides that has been tested and verified by a score of researchers but in this regard the concentration of the exogenous brassinolides is of special matter. It promotes the growth only when applied in proper amounts otherwise it acts in reverse. In most of the cases small concentrations have been found effective. Nguyen *et al*. [55] applied brassinolide in greater concentration and in the end observed that it not only affected the shape of the rice seedlings but also reduced the leaf sheath as compared to plants that were sprayed with smaller concentration of brassinolide [56].

Sorghum Water Extracts Allelopathy: Several weeds infest the cereal fields, among these, wild oat (*Avena fatua* L.), canary grass (*Phalaris minor* L.), lambsquarters (*Chenopodium album* L.) are major weeds, while broadleaf dock (*Rumex dentatus* L.), sweet clover (*Melilotus indica* L.) wild medic (*Medicago polymorpha* L.), crow pea (L*athyrus aphaca* L.) and fieldbind weed *(Convolvulus arvensis* L.) are relatively minor [57, 58, 59, 60]. Weed density, type of weeds, their persistence and crop management practices determine the extent of yield losses [61, 62, 63]. Wheat crop usually suffer from stress created by weeds through competition for water, nutrients [64], space and sunlight [65]. Weeds also cause interference by releasing toxic substances into rhizosphere of crop plants. Allelopathy offers potential for weed control [66, 67, 68] by the production and release of allelochemicals from leaves, flowers, seeds, stems and roots of living or decomposing plant materials. Sorgaab reduced the weeds infestation when it was used with herbicides in low doses [69, 70, 71, 72, 73, 74, 75]. Thus integrating commercial herbicides in low concentration with allelochemicals can be a promising approach in future for sustainable agriculture and to keep the environment safe [76].

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