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Defensive Potential of Sorghum at Biochemical Levels against *Atherigona soccata* (Rondani)

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Abstract

Sorghum bicolor L. is fifth most important cereal crop in the world followed by wheat, rice, maize, and barley. Morphological traits comprises the building of a physical barrier are serves as first line of defense in plant which negatively influenced affects the insect growth, development, existence and attack. On the other hand host-plant resistance mechanism is also one of the best approaches to reduce the attack of insects in plants which stimulates variety of antioxidant enzymes and non-enzymatic antioxidant, proteinase inhibitions, alpha amylase inhibitors secondary metabolites. These biochemical constituents directly involved in detoxification mechanism of elevated level of ROS and provide protection against insect damage.

Introduction

Plants and insects have co-evolved over millennia to overcome and bypass each other defensive responses. This interallia means the capacity to recognize non-self-molecules or signals from damaged cells, setting in motion the plant immune response against various pests and pathogens. Such defensive capabilities are built upon specialized morphological structures, secondary metabolites and proteins that are toxic repellents and anti-nutritional effect on insect infestation. On the other hand, insects have evolved various adaptation strategies to counteract the resistance responses of the host plant, thereby resulting in the increase of insect attack and consequently lead to loss in crop productivity. For instance, plant -insect interactions have been recognized in one of the important food and fodder crop, Sorghum. *Sorghum bicolor* L. is fifth most important cereal crop in the world followed by wheat, rice, maize, and barley. The *Atherigona soccata* (Rodani) commonly known as shoot fly is major constraint which limits productivity of sorghum.

Why Important is Sorghum?

Sorghum is lifeline for poor farmers, cultivated across India during *Kharif* season and *Rabi* seasons due to its wide range of adaptation in different ecological condition in order to meet both green as well dry fodder requirements of the livestock. Livestock as important components of agriculture economy contributed approximately of 4.11% of the total GDP. India faces a net scarce of 61.1% of green fodder, 21.9% of dry crop residue and 64% for feeds (Parmar *et al.,* 2019). Production of healthy livestock directly depends upon production of green fodder and its nutrition composition. Limited supply with poor quality of fodder is considered as major limiting factor for the livestock industry in India. As it is one of the main green fodders, it can be fed to the animals for a longer period without much loss of the nutrients. Fodder quality of sorghum is very important as it contributed by several aspects such as agronomical, genetic, environment and biological factors. Generally, quality and digestibility decrease and content of fiber constituents increases at advancing stage. In India sorghum productivity is lesser with an average yield of 783 kg/ha, which is smaller than the worldwide average yielded of 1,373 kg/ha (Kahate *et al.,* 2014).

Reason for Low Productivity of Sorghum

There are numerous other factors which are responsible for low yield of sorghum among which insect pests are major ones. Due to these insect pests (shoot fly, stem borer, shoot bug, aphid and head bug) full yield potential in sorghum is not recognized (Kahate *et al.,* 2014). About 150 insect pests have been reported on sorghum from seedling to maturity stage. The major constraint which limits productivity of sorghum is the infestation of devastating pest, *Atherigona soccata* (Rodani) commonly known as shoot fly.

Feeding Behavior of Shoot Fly

Shoot fly mostly attack on the seedling stage of sorghum by laying eggs on the lower surface of third to sixth basal leaves near the midrib of sorghum leaves. After shading, maggot travels downward between leaf sheaths and cuts central meristematic tissue of the emerging leaf thereby leading to the formation of 'dead heart' which results in drying and death of central whorl. Due to high fecundity and indiscriminate use of pesticides, it becomes difficult to manage the pest. Thus, pests are major constraints for improvement of farmers' income as they cause immense damage to crop plants which result in low yield, crop productivity and quality of agricultural products. Therefore, an effective strategy is required for the management of shoot fly.

Ecofriendly Strategies to Control Shoot Fly Attack Morphological and Biochemical Responses

Plant and insect co-evolution resulted in the development of defensive capabilities to counter act the effect of one another. Plants are non-mobile and cannot avoid the persistence of the insect infestation thereby protects itself by triggering immune responses. Therefore, a successful pest must be able to grip the total biochemical defense system of the plant. To avoid damages caused by insect, plants continuously sight for new strategies in turn insect always ready to develop counter adaptation. These types of interaction have led to the up regulation of various plant defensive traits, mainly morphological, biochemical, molecular mechanism and hormone signaling and several reports are available indicating that linkage between these pathways.

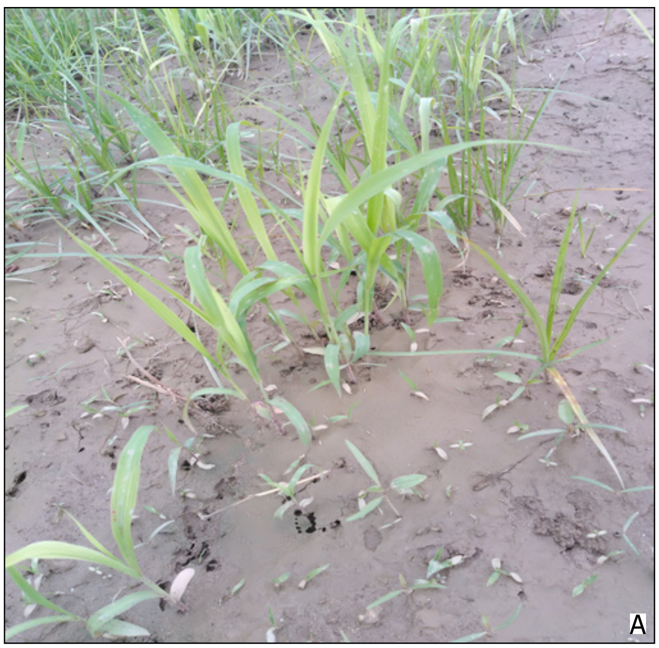
Morphological Responses

First line of defense or morphological traits comprises the building of a physical barrier either through the formation of a spinescence (spines, thorns and prick, waxy cuticle, development of spines, setae), trichomes (pubescence), sclerophylly (toughened or hardened leaves), incorporation of granular minerals into plant tissues and shoots with wiry stems produced at wide axillary angles known as divaricated branching.

Biochemical Responses

Host plant resistance (HPR) is an essential mechanism in insect management responds through numerous molecular, biochemical and morphological mechanisms to counter the effects of insect feeding. This type of defense is known as induced resistance that undesirably affects insect attack, development, and existence. A characteristic primary response of plants is the rapid generation of reactive oxygen species (ROS) or oxidative burst that cause damage to lipids, protein, carbohydrates and nucleic acid and play an adaptable signaling function that mediate multiple responses and can also directly act as toxin. The superoxide radical and hydrogen peroxide are the most important ROS, rapidly accumulated in response to abiotic and biotic stresses.

During stress condition plants stimulates variety of antioxidant enzymes and non-enzymatic antioxidant, proteinase inhibitions, alpha amylase inhibitors secondary metabolites etc. These directly involved in detoxification mechanism of elevated level of ROS and provide protection against insect damage. The antioxidant enzymes comprise superoxide dismutase (SOD), peroxidases (PODs), catalase (CAT), glutathione reductase (GR) on the other side non enzymatic antioxidants such as proline, glycine betain, ascorbate, glutathione hydrogen peroxide (H_2O_2) and malondialdehyde (MDA), secondary wmetabolites including phenols flavones, flavonoles, flavanones, dihydroflavonols, proanthocyanidins and condensed tannins etc. The increased accumulation of ROS in response to herbivory is initiated by the activation of plasma membrane localized NADPH oxidase. NADPH oxidase catalyzes the generation of superoxide radical (O_2^-), by one electron reduction of oxygen using NADPH as the electron donor. SOD serve as first line of defense against harmful effects of elevated levels of ROS induced by insect damaged. The superoxide radicals generated by e.g. NADPH oxidase are dismutated by SOD into O_2 and H_2O_2. This removes the possibility of $OH^{\bullet}$ formation by the Haber-Weiss reaction. Catalase is a major enzyme responsible for H_2O_2 scavenging and functions mainly in the removal of excessive H_2O_2 into water and oxygen generated during developmental or by environmental stresses. The peroxidases are involved in varied range of physiological processes such as cell wall metabolism, lignifications, suberization, auxins metabolism, wound healing, associated with H_2O_2 decomposition against pathogens and insect pest etc. Upregulation of polyphenol oxidase and peroxidase were also documented in sorghum genotypes against shoot fly infestation. Several researcher reported that morphological (trichome density, leaf sheath pigmentation, seedling vigor, glossiness and leaf surface wetness) and biochemical constituent (chlorophyll content, phenolic constituents, polyphenol oxidase and peroxidase) attributes are the factors which play a significant role in imparting resistant to shoot fly (Padmaja *et al.,* 2014). Phenols are regarded to have diverse role in stressed plants such as neutralization of reactive oxygen species (ROS), cell wall lignification and oxidation of phenolics compounds into quinones by peroxidases and polyphenols oxidase. Accumulation of phenolic constituents reduces the nutrition absorption by insect thus inhibit growth and development of insect/ pest.



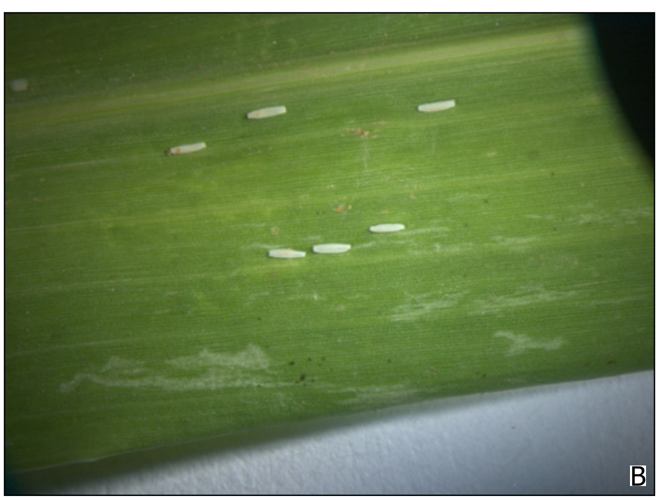


Figure 1: Filed picture of a) uninfested sorghum plants; b) shoot fly eggs; c) sorghum plant with deadheart formation

Conclusion

Taken altogether, along with morphological traits defensive proteins and metabolites are the one of the factor which is responsible for resistance against insect infestation. Overall the scenario to biotic stress is a complex phenomenon with the involvement of morpho-physiological structure, various enzymatic pathways, metabolites and signal molecules to initiate the cascade of events leading to differential behavior of sorghum genotypes toward the insect/ pest attack. Such interrelated morpho-physiological and biochemical response in sorghum against shoot fly infestation can help to understand the resistance mechanism and may help to facilitate novel approaches in crop protection and improvement.

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