This is an open-access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

TRENDS IN ANIMAL AND PLANT SCIENCES
https://doi.org/10.62324/TAPS/2023.016
www.trendsaps.com; editor@trendsaps.com

RESEARCH ARTICLE

Evaluation of Micronutrients on Physio-morphic Traits and Insect Pest Incidence on Maize, *Zea mays* (L).

Aqsa Iqbal[1], Burhan Ali Kanwal[2], Amber Ali[3*] and Aqsa Sohail[4]

[1]Department of Botany, University of Agriculture Faisalabad, Pakistan
[2]Department of Entomology, University of Agriculture Faisalabad, Pakistan
[3]University of Sialkot, Pakistan
[4]Department of Plant Pathology, University of Agriculture Faisalabad, Pakistan
***Corresponding author:** amberalibutt.16@gmail.com

Article History: 23-005 Received: 08-Jul-2023 Revised: 19-Aug-2023 Accepted: 01-Sep-2023

ABSTRACT

Maize is an important crop in the world which is used as a food and in other beneficial items but several insect pests produce harmful effects on the production of maize crop. Current work was done to evaluate the effect of Silicon (Si) and Sulphur (S) alone and in combined form on physio-morphic traits and insect pest incidence on maize plants under field condition. The concentrations of Si 0.4g, 0.6g, and 0.8g and S 0.4g and 0.8g were tested against different insect pests of maize and its physio-morphic traits. Highest population reduction of shoot fly (2.00±0.57) was observed in combined application of Si and S at highest dose rate while minimum was recorded (6.33±1.45) at lowest dose rate of Si (0.4g) alone. Similarly trends in population reduction were recorded for fall army worm, aphids and stem borer of maize. Similarly, significant difference in physio-morphic characters was observed in all treatments. Highest increase in leaf length (97.90±1.18) was observed in combined application of Si and S while at highest dose rate, while lowest was recorded at (60.06±0.91) lowest dose rate of Si (0.4g) compared to control. Similarly, stem diameter, leaf width, plant height and trichome density exhibited the same response towards treatments. It was found that in maize crop, both Si and S enhances the physio-morphic characteristics and induce physical and mechanical defense against insect pest and posed negative impact on insect pest incidence. Application of Si and S is a recommended as a promising strategy to control insect pest to enhance crop production.

Key words: Maize, Silicon (Si), Sulphur (S), Population, Physio-morphic.

INTRODUCTION

Maize (*Zea mays* L.) production continues to be threatened by several insect pests and diseases (Alam *et al*., 2021). From germination to maturity, the plant is threatened by a number of insect pests such as shoot fly (*Atherigona spp.*) (SHAH *et al*., 2023). At germination, seeds are attacked by cutworms (*Agrotis ipsilon Rott.*), wireworms (*Melanotus communis Gyllenhal*), black field earwigs, false wireworms, beetles such as African black beetle and maize stem borer (*Chilo partellus*), corn aphid (*Rhopalosiphum maidis*) (Khan *et al*., 2016). Fall armyworm (FAW) attack on leaves and central shoots (Makgoba *et al*., 2021; Ren et al., 2019; Zafar et al., 2020). In maize, pesticides have been used to control weeds, insects, and fungi across a broad range of applications to improve crop yields (Salem, 2016). Injudicious use of pesticides has serious effects like insecticide resistance and resurgence, which kills beneficial and harmful insects and damages the environment and human health (Mane *et al*., 2020; Iqbal et al., 2016; Zafar et al., 2022; Razzaq et al., 2023).

Integrated management of 13 essential nutrients, seven micronutrients (Fe, B, Mn, Cu, Zn, Cl, Mo) and six macronutrients (N, Mg, K, Ca, P, and S), is typically regarded by agronomists for sustainability and increasing productivity (Aziz *et al*., 2002; Razzaq et al., 2021). However, some elements are not essential, but promote plant growth by changing physiological processes and are said to be beneficial, such as Silicon (Si) (Kamal et al., 2019; Ahmed et al., 2023).

Cite This Article as: Iqbal A, Kanwal BA, Ali A and Sohail A, 2023. Evaluation of micronutrients on physio-morphic traits and insect pest incidence on maize, *Zea mays* (L). Trends in Animal and Plant Sciences 2: 42-50. https://doi.org/10.62324/TAPS/2023.016

Maize is considered a high accumulator of Si as compared to other crops in the grass family (Ahmed *et al*., 2023). Plants treated with Si attract natural predators to host insect herbivores. Si-amended plant tissues are rigid, hard to chew and digest by insects (Zimba *et al*., 2022). Si in plants provide structural strength as well as play a role in biological processes, such as a regulating role in the uptake of other plant nutrients; a role in development and growth; particularly when plants are vulnerable to abiotic stresses (salinity, drought, acidity, etc.) and biotic stresses, because Si increases plant resistance (by encouraging defense reaction mechanisms and decreasing injury from insects and rodents due to strengthening of the plant, also acting as an effective deterrent for herbivores (Guntzer *et al*., 2012).

Plants without silicon are structurally weaker than plants enriched with silicon, showing reduced growth, reproduction, sustainability, and development. In addition, they are more vulnerable to abiotic and biotic stresses (Laane, 2018). It provides a mechanical barrier against insect pests in monocots. Moreover, it has also left no pesticide residue in the environment or in food, and easily integrated with other management practices and biological control against pests (Laing *et al*., 2006). Sulphur (S) is considered a secondary nutrient in agricultural production and is essential for amino acid synthesis (Gill and Tuteja, 2011). Sulphar application affects nitrogen uptake, stress resistance, grain yield, and yield quality of plants. Its deficiency occurs in S-demanding crops such as maize. Under water deficit conditions, sulphur improves maize yield by increasing photosynthesis and chlorophyll content. It is an essential nutrient and is important in the synthesis of proteins in plants along with nitrogen and phosphorus (Ma *et al*., 2021). Involved in the synthesis of amino acids (Métayer *et al*., 2008). It not only improves crop quality but also improves crop management through its positive effects on environmental stress, resistance against pests and diseases (Njira and Nabwami, 2015). It also improves the quality of fodder by reducing nitrate levels in forages. Its deficiency symptoms in corn are yellowing of the younger or new leaves, intervening chlorosis, and reddening of stems and leaves first from the leaf edges (Pagani and Echeverria, 2012).

Involves the production of plant growth hormones for enhancing the growth of plants, such as an increase in leaf length, height of plant, and the leaf area index (Mishra *et al*., 2020). Its application also has an influence on the yield attributes of maize, including the highest cob length, cob weight, grain weight, number of grains/cob, cob weight, cobs/plant, rows per cob (Ali *et al*., 2013). It also increases nitrogen availability and uptake by the plant, improves photosynthetic activity by increasing chlorophyll content, and increases starch utilization; all of these functions increase maize yield and sustainability (Sutar *et al*., 2017; Mansoor et al., 2003).

The current study was designed with an aim to evaluate host plant resistance by using silicon and sulphur on the basis of lower insect pest incidence and to determine the physio-morphic basis of resistance in maize against different insect pests.

MATERIALS AND METHODS

Maize Seed

Certified hybrid maize (*Zea mays* L.) seeds variety DK-8148 Bayer Pakistan (Pvt) limited, were purchased from the pesticides market.

Sources of Silicon and Sulfur

Sulphur was purchased from (FMC united Pvt. limited) pesticides market and Silicon compound silicon di oxide was purchased from a scientific store.

Experimental Site and Design

The field experiment was conducted in Department of Entomology Islamia University of Bahawalpur, Punjab, Pakistan (29.35° N latitude, 71.69° E longitude) on silt-loamy soil. This research site lies in warm desert climate, a mean annual temperature of about 25°C and the annual average precipitation of 233 mm. The trails were laid out in Randomized Complete Block Design (RCBD) under the factorial arrangement with three replications having a plot size of 3m × 2m.

Sowing of Maize

The current trails were performed in field conditions at Department of Entomology Islamia University Bahawalpur, Pakistan 2022. Plastic pots were filled with 2.5 kg of the soil and two seeds of maize were germinated in each plastic pot containing (silty-loam) soil. Sowing was performed on august 22nd. The have been thinned to 1 plant/pot after seven days of seeding and plants were further grown under the green house at temperature of 25 °C, and at ambience sunlight. At the sowing time, plants received Nitrogen, potassium and phosphorus (N:P: K) at the rate of 60 mg/kg of soil. The pots were protected with black plastic sheet to prevent evaporation and exclude light from the roots. Plants were irrigated in order to improve root development before initiating treatments. The size of whole experimental was 3m × 2m, and pot to pot distance was 20 cm respectively. Standard agronomic practices were adopted in the greenhouse throughout the maize growing season. Seedlings were then transferred to the field. The experimental site was left open for natural infestation of insect pests

Silicon and Sulfur Application

Treatments contained Si as Silicon dioxide (SiO2) and Sulphur was applied by Foliar application method (Table 1). Foliar treatments were applied using 200 mL of water per treatment and base of plant covered with plastic sheet to prevent soil absorption. The first Si and S treatment was applied at to the plant after 25 days of seedling emergence, while second application applied at 10 days interval. Total treatments were 11 each with three replications and untreated plants were considered as control check which received no silicon and Sulphur amendment.

Data Collection

Insect Pest Infestation

The experiment was performed under field conditions adopting in Randomized Complete Block Design (RCBD) using Silicon and Sulphur alone and in their possible combinations. The effects of Silicon and Sulphur on different insect pest preference were evaluated.

Table 1: Treatments combination of Silicon and Sulphur tested in the experiment

Treatment Sr. #	Treatment Combinations
T_1	silicon dioxide = 0.4 g
T_2	silicon dioxide = 0.6 g
T_3	silicon dioxide = 0.8g
T_4	Sulphur = 0.6 g
T_5	Sulphur = 0.8 g
T_6	silicon dioxide = 0.4 + Sulphur = 0.6 g
T_7	silicon dioxide = 0.6 g + Sulphur = 0.6 g
T_8	silicon dioxide = 0.8 g + Sulphur = 0.6 g
T_9	silicon dioxide = 0.4 g + Sulphur = 0.8 g
T_{10}	silicon dioxide = 0.6 g + Sulphur 0.8 g
T_{11}	silicon dioxide = 0.8 g + Sulphur = 0.8 g
T_{12}	Control

Statistical Analysis

To determine effect of treatments on the incidence of different insect pests and the physio-morphic traits of maize plant and the application of Si and S and their interaction ware included as independent variables. For data regarding population reduction was taken before spray and after spray and calculated using following formula:

$$\% \text{ Population reduction} = \frac{\text{Population before treatment} - \text{Population after treatent}}{\text{Populaion before treatment}} \times 100$$

The data analyzed by the one-way analysis of variance (ANOVA) in software statistix 8.1 using LSD at 5% significance level.

RESULTS

The results of current study revealed that all the tested treatments of both Silicon and Sulfur were effective against shoot fly, Fall Army Worn (FAW), *Chilo partellus*, and aphid on maize compared to the control. Significant difference against shoot fly was observed in all the treatments for sole as well as combined treatment, after first application ($F_{11, 35}$= 5.06, P ≤0.05) and second application (F $F_{11, 35}$= 8.00, P ≤0.05). Overall, highest population reduction was observed in integrate applications of SiO2 and S at highest dose rate both after first (2.00±0.57) and second (0.66±0.33) application, while minimum was recorded at lowest dose rate of Si (6.33±1.45) compared to control (Fig. 1).

Significant difference against FAW was observed in all the treatments for sole as well as combined treatment, after first application ($F_{11, 35}$= 8.14, P ≤0.05) and second application ($F_{11, 35}$= 9.66, P ≤0.05). Overall, highest population reduction was observed in integrate applications of Si and S at highest dose rate both after first (0.66±0.33) and second (2.00±0.57) application, while minimum was recorded at lowest dose rate of Si (14.00±1.15) compared to control (Fig. 2).

Significant difference against Chilo partellus was observed in all the treatments for sole as well as combined treatment, after first application ($F_{11, 35}$= 5.49, P ≤0.05) and second application ($F_{11, 35}$= 8.58, P ≤0.05). Overall, highest population reduction was recorded in integrate application of Si and S at highest dose rate both after first (0.33±0.33) and second (1.33±0.33) application, while minimum was recorded at lowest dose rate of Si (12.00±1.73) compared to control (Fig. 3).

Significant difference against aphid was observed in all the treatments for sole as well as combined treatment, after first application ($F_{11, 35}$= 18.43, P ≤0.05) and second application ($F_{11, 35}$= 15.70, P ≤0.05). Overall, highest population reduction was observed in integrate application of Si and S at highest dose rate both after first (6.00±1.00) and second (9.66±1.85) application, while minimum was recorded at lowest dose rate of Si (40.66±4.91) compared to control (Fig. 4).

The results of current study revealed that all the tested treatments of both Silicon and Sulfur were effective on physiomorphic traits (Stem diameter, plant height, leaf length, Trichome density, leaf width) of maize compared to the control. Significant difference on stem diameter was observed in all the treatments for sole as well as combined treatment, 25 days after second application ($F_{11, 35}$= 54.06, P ≤0.05). Overall, highest growth rate of stem diameter was recorded in combined application of Si and S at highest dose rate (33.36±1.07) of applications, while minimum was recorded at lowest dose rate of Si (17.25±0.72) compared to control (Fig. 5).

Significant difference on Plant height (cm) was observed in all the treatments for sole as well as combined treatment, 25 days after second application ($F_{11, 35}$= 107.61, P ≤0.05). Overall, highest growth rate of plant height was observed in integrate application of Si and S at highest dose rate (181.44±1.05) application, while minimum was recorded at lowest dose rate of Si (116.13±4.22) compared to control (Fig. 6).

Significant difference on leaf length (cm) was observed in all the treatments for sole as well as combined treatment, 25 days after second application ($F_{11, 35}$= 34.76, P ≤0.05). Overall, highest growth rate of leaf length was recorded in combined application of Si and S at highest dose rate (97.90±1.18) application, while minimum was recorded at lowest dose rate of Si (60.06±0.91) compared to control (Fig. 7).

Significant difference on trichome density 2cm^2 was observed in all the treatments for sole as well as combined treatment, 25 days after second application ($F_{11, 35}$= 51.31, P ≤0.05). Overall, highest growth rate of

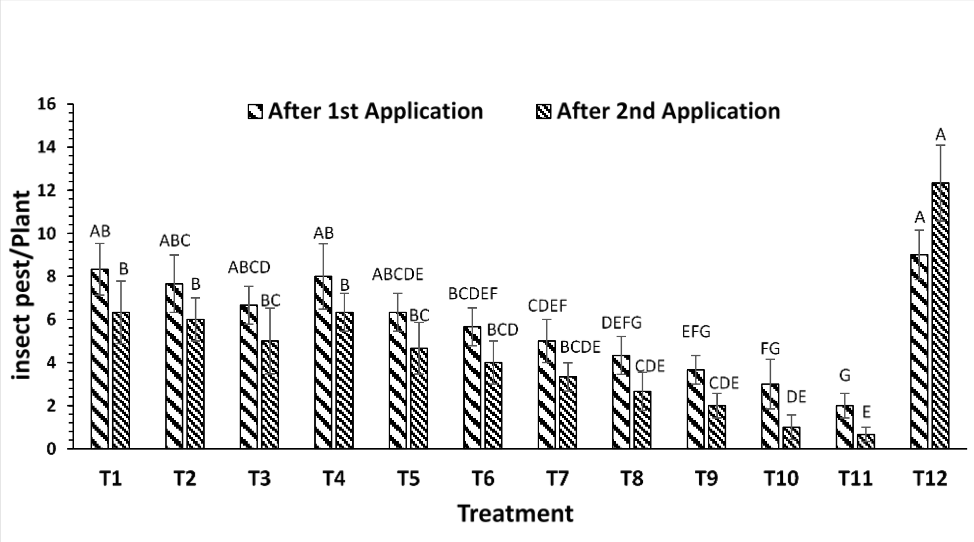

Fig. 1: Mean number (±SE) of Shoot fly larvae and adults 10 days after first and second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test $P \leq 0.05$, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

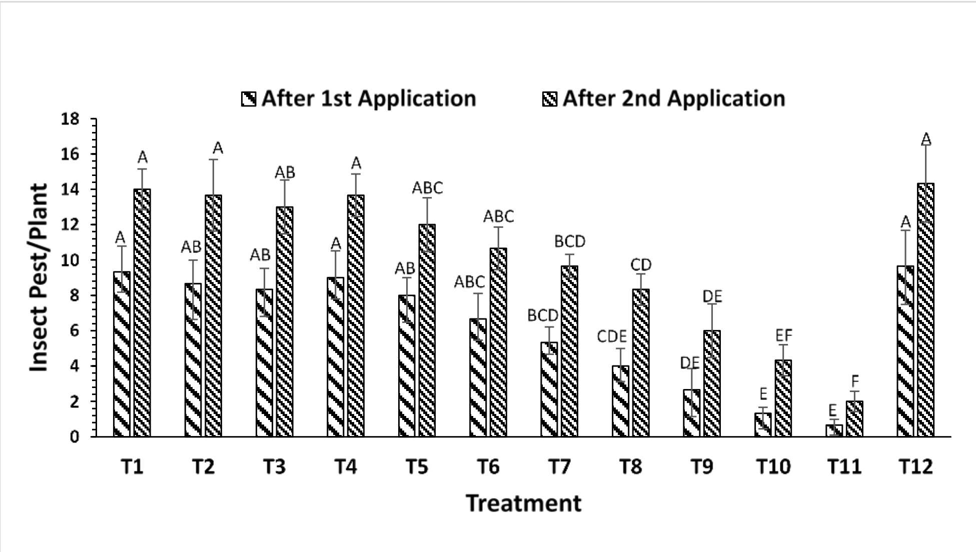

Fig. 2: Mean number (±SE) of Fall Army Worm (FAW) larvae and adults 10 days after first and second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test $P \leq 0.05$, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

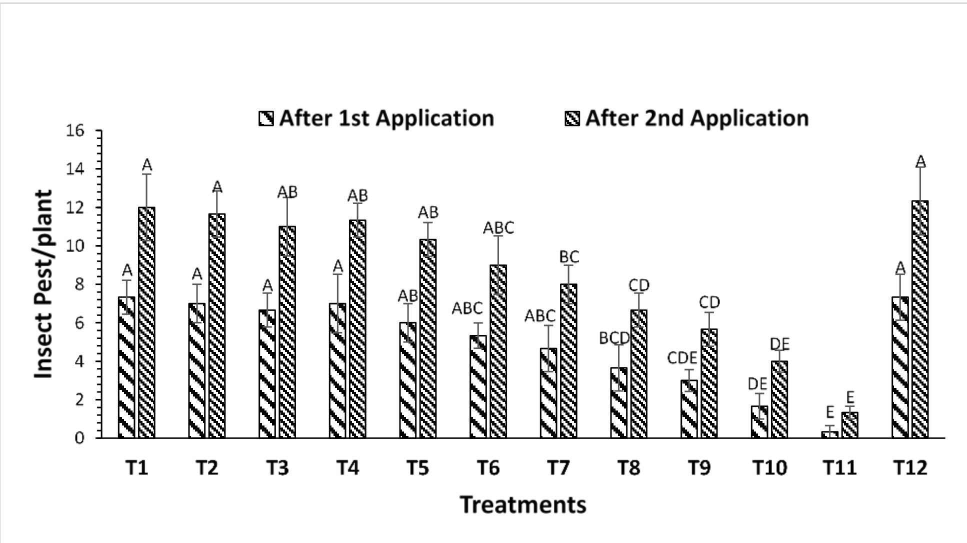

Fig. 3: Mean number (±SE) of Chilo partellus larvae and adults 10 days after first and second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test $P \leq 0.05$, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

trichome density was recorded in integrate application of Si and S at highest dose rate (155.00±2.30) application, while minimum was recorded at lowest dose rate of Si (116.00±2.64) compared to control (Fig. 8).

Significant difference on leaf width (cm) was observed in all the treatments for sole as well as combined treatment, 25 days after second application ($F_{11, 35}$=126.06, $P \leq 0.05$). Overall, highest growth rate of stem diameter was observed in integrate application of

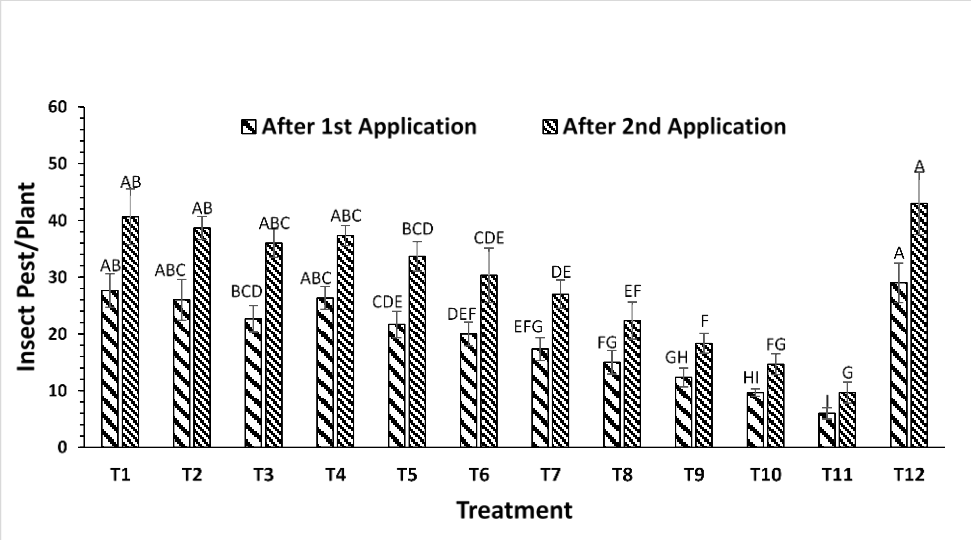

Fig. 4: Mean number (±SE) of Aphid larvae and adults 10 days after first and second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test *P* ≤ 0.05, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

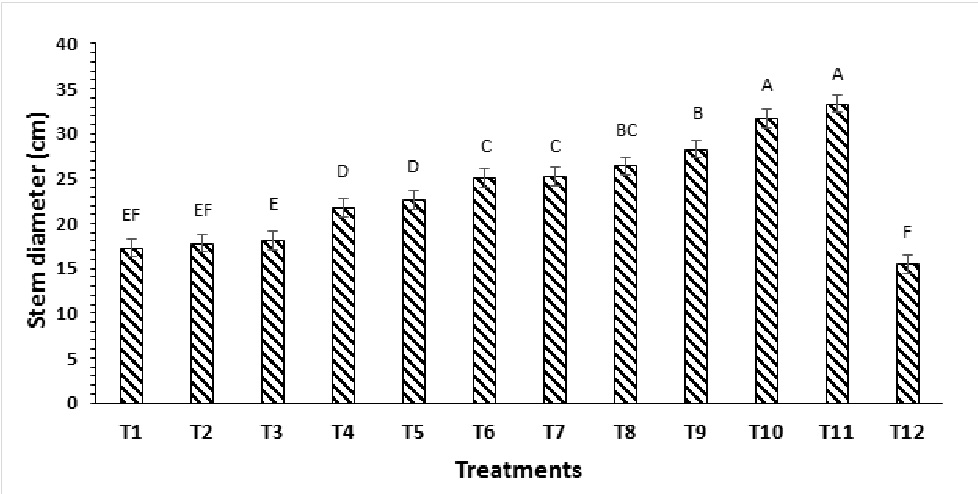

Fig. 5: Mean number (±SE) of Stem diameter (cm) 25 days after second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test *P* ≤ 0.05, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

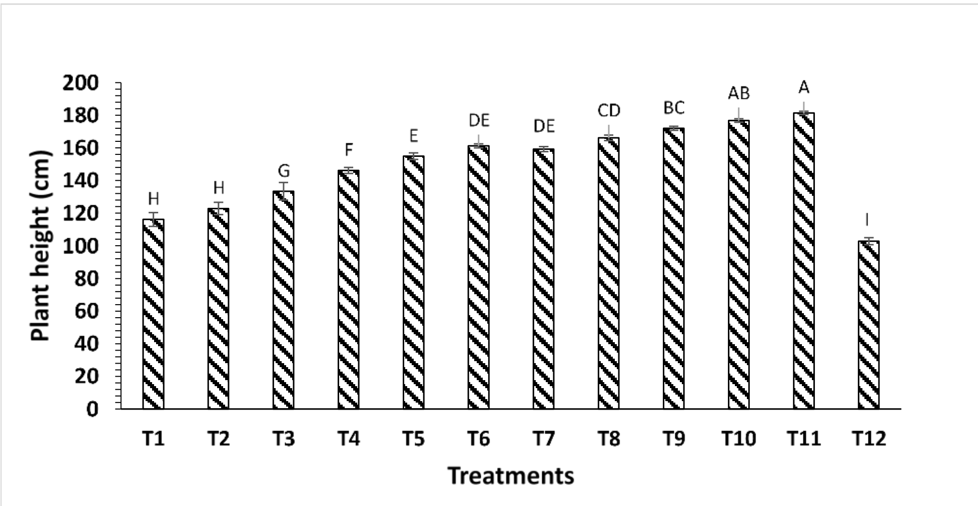

Fig. 6: Mean number (±SE) of Plant height (cm) 25 days after second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test *P* ≤ 0.05, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

Si and S at highest dose rate (13.43±0.37) application, while minimum was recorded at lowest dose rate of Si (7.00±0.11) compared to control (Fig. 9).

DISCUSSION

The purpose of our study was to investigate effects of Silicon and Sulphur against insect pest incidence of fall army worm, aphid, shoot fly, *Chilo partellus* (Alam *et al*., 2021) and also on the physiomorphic characteristics of maize crop (Adhikary *et al*., 2010). Both Si sources K_2SiO_3 and SiO_2 cause a reduction in viability, increased growth period, decrease biomass and lipase activity (Abbasi *et al*., 2022). In leaves increased concentration of Si causes instinctive stability and which increases the defensive ability of plant against insects and the effect on the

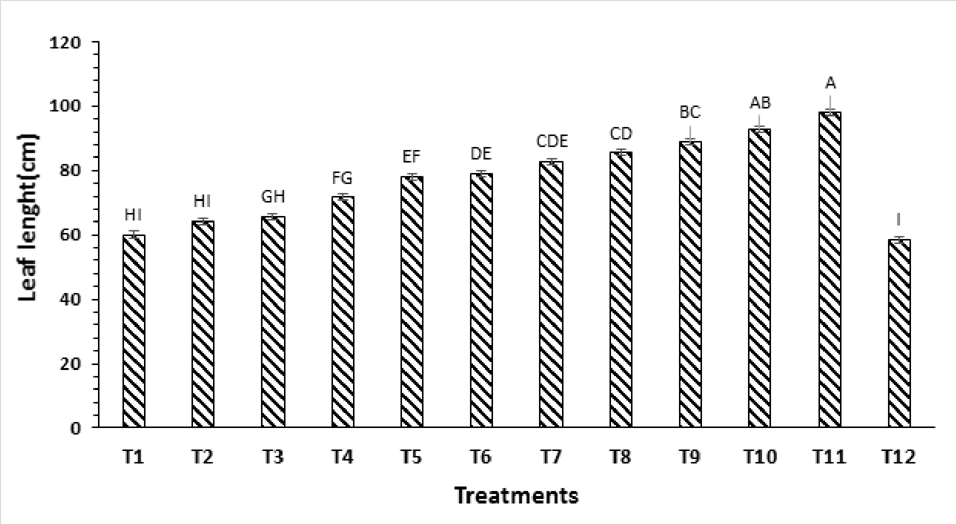

Fig. 7: Mean number (±SE) of Leaf length (cm) 25 days after second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test $P \leq 0.05$, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

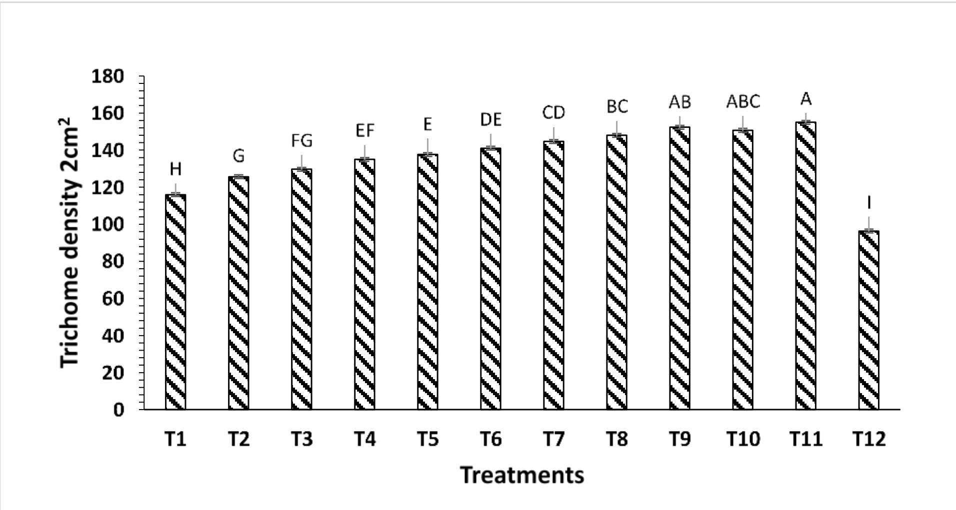

Fig. 8: Mean number (±SE) of Trichome density 2cm² 25 days after second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test $P \leq 0.05$, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

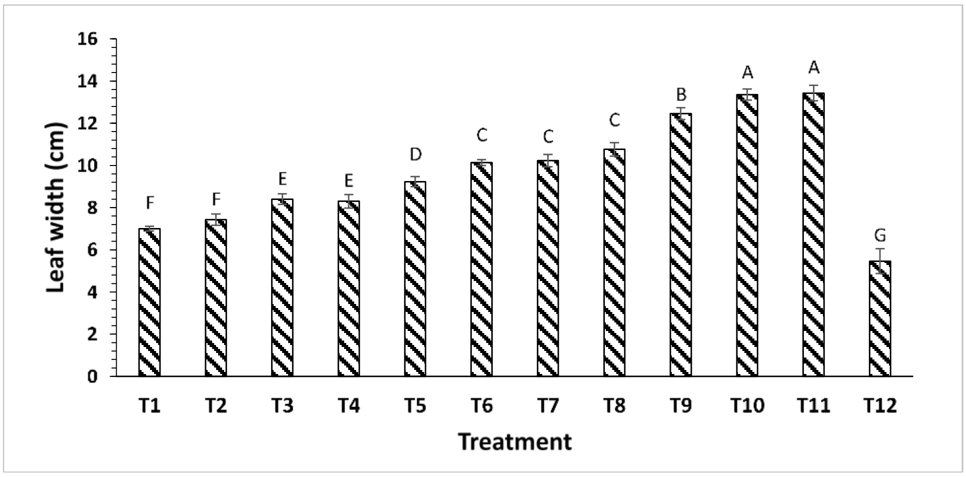

Fig. 9: Mean number (±SE) of Leaf width 25 days after second application of Silicon (Si) and Sulfur (S) alone and in combination. Mean followed by the same letters on subsequent bars are not significantly different; HSD test $P \leq 0.05$, Silicon (Si) and Sulfur (S) were applied; **T_1:** Si= 0.4g, **T_2:** Si= 0.6g, **T_3:** Si= 0.8g, **T_4:** S= 0.6g, **T_5:** S= 0.8g, **T_6:** T_1+T_4, **T_7:** T_1+T_5, **T_8:** T_2+T_4, **T_9:** T_2+T_5, **T_{10}:** T_3+T_4, **T_{11}:** T_3+T_5, **T_{12}:** Control

development of fall army worm, shoot fly, aphid and *Chilo partellus* was also detected. Si also play important to induce plant resistance. Si produced negative effect on insect development.

The toxic effects of Si treated plants is increase in the rigidity and decrease in the digest ability of leaf which reduce growth of larvae by the accumulation of silicon material in cell wall of the plants. Sulphur, a major macronutrient, is one of important nutrients that enhance the plant growth. Sulphur mainly affects the physiomorphic properties in maize crop such as fresh and dry weight, grain yield with enhance Height of plants, width of leaves, stem diameter and trichome density. Sulphur plays a key role in photosynthesis. In the current research, we aim to protect the maize crop from effects of different insects by using macronutrients Sulphur and Silicon. Results of this study showed that not only insect performance effected by silicon or sulphur treatments but also show positive affect on physio-morphic characteristics of maize plant.

Results of this work revealed that sole as well as combined applications of silicon and sulphur affected the physiomorphic characteristics of maize crop and insect pest incidence. All the tested treatments of both silicon and sulphur were effective against shoot fly compared to the untreated plants. A remarkable effect was observed for sole as well as combined treatment after first application and second application. Overall highest population reduction was observed in integrate application of SiO2 and S at highest dose rate both after first and second application while minimum was recorded at lowest dose rate of Si compared to control.

Similarly all the treatments were effective against fall army worm, aphid and *Chilo partellus*, greater reduction in population of all insects was recorded in combined application of (Si 0.4g+ s 0.6g), (Si 0.6g+S 0.6g), (Si 0.8g+S 0.6g), (Si 0.4g+S 0.8g), (Si 0.6g+S 0.8g), (Si 0.8g+S 0.8g) while minimum was recorded at (Si 0.4g), (Si 0.6g), (Si 0.8g), (S 0.6g), (S 0.8g) lowest dose rate of Si or S compared to control. Silicon and sulphur proved effective for physio-morphic characteristic such as height of plant, Length of leaf, Width of leaves, stem diameter and trichome density of maize plant. Lesser effect was recorded in term of trichome density.

Lowest increase in stem diameter (17.25 mm) compared to control (15.49 mm) was observed at Si (0.4g) while highest increase in stem diameter (33.36 mm) was observed in combined application of (Si 0.8g +s 0.8g). Similarly, less improvement in plant height (116.13 cm) as compared to normal was observed at Si (0.4g) while highest increase (181.44 cm) was observed in integrate application of SiO2 and S (0.8g+0.8g). In case of leaf length lowest increase (60.06 cm) compared to control (58.30 cm) was recorded at 0.4g Si while maximum increase was observed in combined application of Si and S (0.8g+0.8g). Lowest effect on leaf width (7.00 cm) at 0.4 g Si compared to control 5.46 cm while maximum difference in leaf width was observed in combined application of Si and S (0.8g+0.8g).

Lowest effect at trichome density of 2cm^2 area of leaf 116.00 trichome was recorded at 0.4g Si compared to control 96.33 trichome while highest increase 155 trichome was observed in combined application of Si and S (0.8g+0.8g). Overall significant difference was recorded in all treatments of silicon and sulphur for sole as well as combined treatments. Adult phase parameters of fall army worm were affected when treated with silicon and gibberellin acid. When plants treated with these substances fed to the females derived from larvae showed significant effect on their fecundity. Si mostly affect the insect fecundity (Alvarenga *et al*., 2017). Observed that fewer eggs were produced per female from male and female pairs of fall army worm which fed on silicon treated cotton leaves (Silva *et al*., 2014). Indicated that *Nilaparvata lugens* (stal) showed reduction in fecundity by feeding on silicon treated rice plant. Silicon accumulation produced significant effect on oviposition by which defence metabolites activated and increased. Additional studies demonstrated that fecundity of insects (mainly of aphid) reduces when treated with silicon (Yang *et al*., 2017). Indicated that *B. tabacci* when fed with Sio_2 treated plants increased longevity compared to the untreated control (Abbasi *et al*., 2022). Significant difference was observed on stem length, chlorophyll and enzyme activity of maize plant. It is stated in many studies that plants treated with silicon application shows significant effect on growth of plant and their yield also (Haq *et al*., 2021). Silicon application of barley produces significant increase in fresh weight (Dresler *et al*., 2015).

Dynamics and availability of sulphur are less studied than other nutrients, while for crop production sulphur is a vital nutrient (Rheinheimer *et al*., 2007) and produce positive effect on growth parameters of maize crop. Mostly sulphur is found in organic material and found abundantly in upper layer. For plant growth and development sulphur considered as an essential nutrient because sulphur is a part of important metabolic compounds such as glutathione, proteins, amino acid and sulpho lipids (Duke and Reisenauer, 1986). Dry weight of maize increased with the increased rate of sulphur, after which dry weight of maize decreased, which occurs due to increased concentration of Manganese and Zinc in soil and their take by maize plant (Karimizarchi *et al*., 2015).

Yield of corn enhanced with use of Sulphur as compared to untreated plants. Sulphur and nitrogen have significant effect on the growth properties, oil content and seed quality of two genotypes of soybean. Various studies on sulphur cover the effects of sulphur on maize or other beneficial crops. Sulphur mainly increases the protein yield as we know it is a major part of amino acids so it has a great impact on plant growth. Our results show significant increase with increasing dose of sulphur. Maximum increase is observed in plant height compared to control so it is evident that sulphur has greater effect on growth parameters of maize. Growth is greatly enhanced with Sulphur applications with significant improvement in Leaf width, Leaf length, plant height, stem diameter and trichome density.

Conclusion

In this study we concluded that in maize crop, both silicon and Sulphur present economically viable method and environmentally friendly approach to insect pest control. Integrated management of micronutrients for sustainability and increasing productivity. Silicon or Sulphur enhances the physio-morphic characteristics in plant such as leaf of length, plant height, leaf width but lesser effect on trichome density. Si and S induced physical defense. Silicon or Sulphur both produce positive effect in physiomorphic characters such as growth, length and also reduce the insect pest incidence. Silicon enhances plant resistance against insect pest and produce rigidity in plants. Integrated use of silicon and Sulphur will be valuable to increase crop productivity and enhance insect pest resistance.

REFERENCES

Abbasi, A., Sufyan, M., Ashraf, H.J., Zaman, Q. U., Haq, I. U., Ahmad, Z. and Ghareeb, R. Y. (2022). Determination of silicon accumulation in non-Bt cotton (Gossypium hirsutum) plants and its impact on fecundity and biology of whitefly (Bemisia tabaci) under controlled conditions. *Sustainability*, *14*(17), 10996.

Adhikary, B. H., Shrestha, J. and Baral, B. R. (2010). Effects of micronutrients on growth and productivity of maize in acidic soil. *International Research Journal of Applied and Basic Sciences*, *1*(1), 8-15.

Ahmed, S. R., Anwar, Z., Shahbaz, U., Skalicky, M., Ijaz, A., Tariq, M. S., ... & Zafar, M. M. (2023). Potential Role of Silicon in Plants Against Biotic and Abiotic Stresses. *Silicon*, *15*(7), 3283-3303.

Alam, S., Khalid, M. N., Ijaz, M., Akram, M. S., Irfan, M. and Hassan, M. (2021). Rearing of Maize Stem Borer, Chilo partellus (Lepidoptera: Crambidae) under Laboratory Conditions.

Ali, A., Iqbal, Z., Hassan, S.W., Yasin, M., Khaliq, T. and Ahmad, S. (2013). Effect of nitrogen and sulphur on phenology, growth and yield parameters of maize crop. *Science International*, *25*(2), 363-366.

Alvarenga, R., Moraes, J. C., Auad, A. M., Coelho, M. and Nascimento, A. M. (2017). Induction of resistance of corn plants to Spodoptera frugiperda (JE Smith, 1797) (Lepidoptera: Noctuidae) by application of silicon and gibberellic acid. *Bulletin of Entomological Research*, *107*(4), 527-533.

Aziz, T., Gill, M. A. and Rahmatullah (2002). Silicon nutrition and crop production: a review. *Pakistan Journal Agriculture Science,* 39(3).

Dresler, S., Wójcik, M., Bednarek, W., Hanaka, A. and Tukiendorf, A. (2015). The effect of silicon on maize growth under cadmium stress. *Russian Journal of Plant Physiology*, *62*(1), 86-92.

Duke, S. H. and Reisenauer, H. M. (1986). Roles and requirements of sulfur in plant nutrition. *Sulfur in Agriculture*, *27*, 123-168.

Gill, S. S. and Tuteja, N. (2011). Cadmium stress tolerance in crop plants: probing the role of sulfur. *Plant Signaling & Behavior*, 6(2), 215-222.

Guntzer, F., Keller, C. and Meunier, J. D. (2012). Benefits of plant silicon for crops: a review. *Agronomy for Sustainable Development*, *32*(1), 201-213.

Haq, I. U., Khurshid, A., Inayat, R., Zhang, K., Liu, C., Ali, S. and Abbasi, A. M. (2021). Silicon-based induced resistance in maize against fall armyworm [Spodoptera frugiperda (Lepidoptera: Noctuidae)]. *Plos one*, *16*(11), e0259749.

Iqbal, Z., Sattar, M. N., & Shafiq, M. (2016). CRISPR/Cas9: a tool to circumscribe cotton leaf curl disease. Frontiers in Plant Science, 7, 475.

Kamal, H., Minhas, F. U. A. A., Farooq, M., Tripathi, D., Hamza, M., Mustafa, R., ... & Amin, I. (2019a). In silico prediction and validations of domains involved in Gossypium hirsutum SnRK1 protein interaction with cotton leaf curl Multan betasatellite encoded βC1. *Frontiers in Plant Science*, *10*, 656.

Karimizarchi, M., Aminuddin, H., Khanif, M. Y. and Radziah, O. (2015). Elemental sulphur effects on nitrogen loss in Malaysian high pH Bintang Series soil. *Malaysian Journal of Soil Science*, *19*, 83-94.

Khan, I. A., Shah, B., Khan, A., Zaman, M., Din, M. M. U., Shah, S. R. A. and Rahman, I. U. (2016). Screening of different maize Cultivars against maize shootfly and red pumpkin beetle at Peshawar. *Journal Entomology Zool. Stud*, *4*(1), 324-327.

Laane, H. M. (2018). The effects of foliar sprays with different silicon compounds. *Plants*, *7*(2), 45.

Laing, M. D., Gatarayiha, M. C. and Adandonon, A. (2006). Silicon use for pest control in agriculture: a review. In *Proceedings of the South African Sugar Technologists' Association* (Vol. 80, pp. 278-286).

Ma, Y., Zhang, H., Xue, Y., Gao, Y., Qian, X., Dai, H. and Li, Z. (2021). Effect of sulfur fertilizer on summer maize grain yield and soil water utilization under different irrigation patterns from anthesis to maturity. *Agricultural Water Management*, *250*, 106828.

Makgoba, M. C., Tshikhudo, P. P., Nnzeru, L. R. and Makhado, R. A. (2021). Impact of fall armyworm (Spodoptera frugiperda) (JE Smith) on small-scale maize farmers and its control strategies in the Limpopo province, South Africa. *Jàmbá: Journal of Disaster Risk Studies*, *13*(1).

Mane, C.B., Bidwe, K.U., Shelke, R.R., Satpute, N.S. and Kahate, P.A. (2021) Studies on Pesticides Residual Effect on Maize and Lucern Green Fodder. Biological Forum - An International Journal 13(3): 05-07.

Mansoor, S., Amin, I., Iram, S., Hussain, M., Zafar, Y., Malik, K., & Briddon, R. (2003). Breakdown of resistance in cotton to cotton leaf curl disease in Pakistan. Plant pathology, 52(6), 784-784.

Métayer, S., Seiliez, I., Collin, A., Duchêne, S., Mercier, Y., Geraert, P. A. and Tesseraud, S. (2008). Mechanisms through which sulfur amino acids control protein metabolism and oxidative status. *The Journal of Nutritional Biochemistry*, *19*(4), 207-215.

Mishra, G. C., Avinash, K., Duvvada, S. K., Supriya, B., Mishra, G. and Satapathy, A. (2020). Response of hybrid sweet corn (Zea mays saccaharata) to fertility levels with and without gibberellin on production potential and economics in Southern Odisha. *Journal of Pharmacognosy and Phytochemistry*, *9*(4), 242-245.

Njira, K. O. and Nabwami, J. (2015). A review of effects of nutrient elements on crop quality. *African Journal of Food, Agriculture, Nutrition and Development*, *15*(1), 9777-9793.

Pagani, A. and Echeverría, H. E. (2012). Influence of sulfur deficiency on chlorophyll-meter readings of corn leaves. *Journal of Plant Nutrition and Soil Science*, *175*(4), 604-613.

Razzaq, A., Ali, A., Zafar, M. M., Nawaz, A., Xiaoying, D., Pengtao, L., ... & Youlu, Y. (2021). Pyramiding of cry toxins and methanol producing genes to increase insect resistance in cotton. *GM Crops & Food*, *12*(1), 382-395.

Razzaq, A., Ali, A., Zahid, S., Malik, A., Pengtao, L., Gong, W., ... & Zafar, M. M. (2023). Engineering of cry genes "Cry11 and Cry1h" in cotton (Gossypium hirsutum L.) for protection against insect pest attack. *Archives of Phytopathology and Plant Protection*, *56*(5), 384-396.

Ren, M., Zafar, M. M., Mo, H., Yang, Z., & Li, F. (2019). Fighting against fall armyworm by using multiple genes pyramiding and silencing (MGPS) technology. *Sci China Life Sci*, *62*(12), 1703-6.

Rheinheimer, D.D.S., Rasche, J.W.A., Osorio Filho, B.D. and Silva, L.S.D. (2007). Response to sulfur application and recovery in greenhouse crops in soils with different clay and organic matter contents. *Rural Science*, *37* , 363-371.

Salem, R. E.M. E. (2016). Side effects of certain pesticides on chlorophyll and carotenoids contents in leaves of maize and tomato plants. *Middle East J*, *5*(4), 566.

Shah, J., Ramzan, U., Naseer, S., Khalid, M., Amjad, I., Majeed, T., Sabir, W., Shaheen, M., Ali, B. and Shahmim, F. (2023).

Chemical Control Of Southern Leaf Blight Of Maize Caused By Helminthosporium Maydis. *Biological And Clinical Sciences Research Journal* 2023, 225-225.

Silva, A.A., Alvarenga, R., Moraes, J.C. and Alcantra, E. (2014). Biology of Spodoptera frugiperda (JE Smith) (Lepidoptera: Noctuidae) on silicon-treated colored fiber cotton. *EntomoBrasilis* , 7 (1), 65-68.

Sutar, R. K., Pujar, A. M., Kumar, B. A. and Hebsur, N. S. (2017). Sulphur nutrition in maize-a critical review. *International Journal Pure App Biosci*, 5(6), 1582-1596.

Yang, L., Han, Y., Li, P., Wen, L. and Hou, M. (2017). Silicon amendment to rice plants impairs sucking behaviors and population growth in the phloem feeder Nilaparvata lugens (Hemiptera: Delphacidae). *Scientific Reports*, *7*(1), 1-7.

Zafar, M. M., Razzaq, A., Farooq, M. A., Rehman, A., Firdous, H., Shakeel, A., ... & Ren, M. (2020). Insect resistance management in Bacillus thuringiensis cotton by MGPS (multiple genes pyramiding and silencing). *Journal of Cotton Research*, *3*(1), 1-13.

Zafar, M. M., Mustafa, G., Shoukat, F., Idrees, A., Ali, A., Sharif, F., ... & Li, F. (2022c). Heterologous expression of cry3Bb1 and cry3 genes for enhanced resistance against insect pests in cotton. *Scientific Reports*, *12*(1), 10878.

Zimba, K. J., Read, Q. D., Haseeb, M., Meagher, R. L. and Legaspi, J. C. (2022). Potential of Silicon to Improve Biological Control of Fall Armyworm, Spodoptera frugiperda on Maize. *Agriculture*, *12*(9), 14.