International Journal of Research Studies on Environment, Earth, and Allied Sciences (IJRSEAS)
| Volume-2 Issue--5 | October-2025 | ISSN: 3066-0637 | Website: https://eesrd.us

Manuscript ID:
IJRSEAS-2025-020528

OPEN ACCESS

Quick Response Code:

Website: https://eesrd.us

DOI: 10.5281/zenodo.18144450

DOI Link:
https://doi.org/10.5281/zenodo.18144450

Volume: 2

Issue: 5

Pp. 155-161

Month: October

Year: 2025

E-ISSN: 3066-0637

***Submitted:* 15 Sept. 2025**

***Revised:* 25 Sept. 2025**

Accepted: *16 Oct. 2025*

***Published:* 31 Oct. 2025**

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How to cite this article:
Waghmode, H. U., & Samudra, S. M. (2025). Biochemical Analysis of Healthy and Infected Soybean Plants with Fusarium solani and Fusarium oxysporum. International Journal of Research Studies on Environment, Earth, and Allied Sciences, 2(5), 155–161. https://doi.org/10.5281/zenodo.18144450

Biochemical Analysis of Healthy and Infected Soybean Plants with *Fusarium solani* and *Fusarium oxysporum*

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Abstract

Soybean is an economically important legume crop that is severely affected by soil-borne fungal pathogens, particularly Fusarium oxysporum and Fusarium solani which cause root rot and wilt diseases. The present study investigates 14 minerals. It was observed that due to infection of F. oxysporum and F. solani, there was noticeable reduction in the Starch, Reducing sugar, and Total sugar, DNA, Potassium, Calcium, Magnesium, Sulphur, Sodium, Zinc, Ferrous, Copper, Manganese and Molybdenum. Whereas Polyphenols, RNA and Ash were increased in infected Soybean plants. This may be in response to host.

The present investigation evaluates the biochemical and mineral alterations in healthy and infected soybean roots to understand host–pathogen interactions and disease-induced metabolic shifts. Quantitative analysis revealed that infection by both Fusarium species resulted in a marked decline in starch, reducing sugars, total sugars, DNA content, and essential macro- and micronutrients including potassium, calcium, magnesium, sulphur, sodium, zinc, iron, copper, manganese, and molybdenum. These reductions indicate disruption of carbohydrate metabolism, nucleic acid stability, and nutrient uptake due to fungal colonization and root tissue damage. Conversely, infected plants exhibited increased levels of polyphenols, RNA, and ash content, reflecting the activation of defense responses and enhanced synthesis of stress-related biomolecules. Comparative analysis further indicated that F. solani induced relatively more pronounced biochemical changes and higher polyphenol accumulation than F. oxysporum, suggesting a more aggressive pathogenic impact. Overall, the study highlights that Fusarium infection leads to nutritional depletion and metabolic imbalance in soybean roots while simultaneously triggering host defense mechanisms, providing insights useful for disease management and crop improvement strategies.

Keywords: *Soybean, Fusarium oxysporum, Fusarium oxysporum*

Introduction

Soybean (*Glycine max* L.) is one of the most economically important legume crops worldwide, valued for its high protein and oil content and its contribution to soil fertility through biological nitrogen fixation (Hartman et al., 2011). However, soybean productivity is severely affected by several biotic stresses, among which soil-borne fungal pathogens pose a major threat. Species of the genus *Fusarium*, particularly *Fusarium oxysporum* and *Fusarium solani*, are widely distributed pathogens responsible for root rot and wilt diseases, leading to substantial yield losses and reduced crop quality (Leslie & Summerell, 2006; Wrather & Koenning, 2009). *Fusarium oxysporum* causes vascular wilt by colonizing xylem tissues, resulting in blockage of water and nutrient transport, chlorosis, wilting, and eventual plant death (Agrios, 2005). In contrast, *Fusarium solani* is primarily associated with root rot and sudden death syndrome, causing extensive damage to root systems and impairing nutrient absorption (Hartman et al., 2015). Infection by these pathogens disrupts normal physiological and metabolic processes, ultimately affecting plant growth and productivity.

Pathogen invasion induces significant biochemical and nutritional alterations in host plants. Carbohydrates such as starch and sugars are often reduced in infected plants due to increased respiratory demand, pathogen utilization, and impaired photosynthesis (Singh et al., 2017). Similarly, nucleic acid metabolism is affected during disease development, with alterations in DNA and RNA content reflecting changes in cell division, transcriptional activity, and defense gene expression (Lozovaya et al., 2004). Mineral nutrients also play a crucial role in plant defense and metabolism; deficiencies or imbalances of macro- and micronutrients such as potassium, calcium, magnesium, sulphur, iron, zinc, copper, manganese, sodium, and molybdenum can weaken structural integrity, enzyme activity, and stress tolerance in infected plants (Marschner, 2012).

Conversely, plants activate defense mechanisms in response to pathogen attack, often resulting in increased accumulation of polyphenolic compounds and changes in ash content. Polyphenols contribute to resistance through antimicrobial activity, lignification, and scavenging of reactive oxygen species (Nicholson & Hammerschmidt, 1992). Enhanced RNA content in infected tissues is frequently associated with increased synthesis of defense-related proteins and enzymes involved in stress responses (Taiz et al., 2015).

In view of these considerations, the present study was undertaken to evaluate the biochemical and mineral changes in healthy and *Fusarium*-infected soybean plants. The study focuses on fourteen mineral elements along with key biochemical constituents to elucidate the impact of *F. oxysporum* and *F. solani* infection and to better understand host responses under disease stress conditions.

Material and Methods:

In the current study healthy roots as well as infected roots by both pathogen of Soybean crop were analyzed, for following parameters viz. Starch and Reducing sugar, Total sugar by Nelson (1944), Polyphenol by Folin and Denis (1951), DNA, RNA by Burton K. (1956) and Total ash by (AOAC,1990) Minerals were also estimated (Toth et. al. 1948).

Result and Discussion:

Biochemical Alterations (Tables 1 & 3 Figures 1,2 & 5,6)

Infection by both *F. oxysporum* and *F. solani* led to a significant depletion of energy reserves in soybean roots. Starch content decreased from 1.67 to 1.546 g/100g (*F. oxysporum*) and 1.72 to 1.59 g/100g (*F. solani*). Similarly, total sugars and reducing sugars showed a marked decline in infected tissues.

By considering defense compounds, a notable increase in polyphenol content was observed in infected roots (0.468 g/100g for *F. oxysporum* and 0.528 g/100g for *F. solani*) compared to healthy counterparts. At the same time, DNA levels decreased upon infection, while RNA levels increased (e.g., from 0.057 to 0.065 mg/g in *F. oxysporum*). There was a slight increase in total ash percentage in infected roots for both pathogens.

Mineral Profile (Tables 2 & 4, Figures 3,4 & 7,8)

The mineral composition of soybean roots was generally negatively impacted by fungal infection: Macronutrients such as Nitrogen (N), Potassium (K), Phosphorus (P), Calcium (Ca), and Magnesium (Mg) all decreased in infected roots. The most significant drop was seen in Sodium (Na) and Potassium (K). Essential trace elements including Zinc (Zn), Ferrous (Fe), Manganese (Mn), and Boron (B) showed a consistent reduction in infected tissues across both *Fusarium* species. A slight reduction in moisture content was recorded in diseased roots.

The biochemical and mineral changes observed in soybean roots following infection by *F. oxysporum* and *F. solani* reflect the metabolic cost of pathogenesis and the plant's subsequent defense response.

Depletion of Sugars and Starch

The reduction in starch and sugars (reducing and total) suggests that the invading fungi utilize the host's soluble carbohydrates as a primary energy source for mycelial growth and sporulation. *Fusarium* species are known to secrete enzymes that break down complex polysaccharides into simpler sugars for absorption (Agrios, 2005). The decline in total sugars is particularly sharp, indicating high metabolic consumption by the pathogen.

Accumulation of Polyphenols

The increase in polyphenols is a classic defense mechanism. Plants synthesize phenolic compounds to create a toxic environment for the fungus and to strengthen cell walls through lignification (Lattanzio et al., 2006). This "oxidative burst" and subsequent phenolic accumulation are intended to restrict fungal penetration, explaining why the infected roots show higher values than healthy ones.

Nucleic Acid Dynamics

The decrease in DNA content in infected roots may be attributed to the degradation of host nuclei during cell death (necrosis) caused by fungal toxins. Conversely, the increase in RNA likely reflects increased transcriptional activity as the plant produces pathogenesis-related (PR) proteins and enzymes for the biosynthesis of secondary metabolites like phenols (Sudarshana et al., 2011).

Mineral Imbalance

The general decline in minerals (N, P, K, Zn, Fe) suggests a disruption in the root's physiological function. *Fusarium* species cause vascular wilting and root rot, which severely impair the root's ability to uptake water and nutrients from the soil. The reduction in K is critical as it regulates osmotic potential and enzyme activation; its loss leads to loss of turgor and increased susceptibility to toxins (Marschner, 2012). The decrease in Zn, Fe, and Mn may be due to the pathogen competing for these elements or the physical destruction of the cortical tissues responsible for ion transport.

Conclusion

Both *F. oxysporum* and *F. solani* cause nutritional starvation in soybean roots. However, the data suggests that *F. solani* induced slightly more pronounced biochemical changes and a higher polyphenol response, indicating a potentially more aggressive interaction with the host tissue compared to *F. oxysporum*.

Table 1. Biochemical Analysis of Healthy and Infected Roots of Soybean by *F. oxysporum*

Sr. No.	Estimation	Healthy Soybean root	Infected Soybean root
1	Starch (g/100g dry wt)	1.67	1.546
2	Reducing sugar (g/ 100g dry wt)	0.163	0.152
3	Total sugar (g/100g dry wt)	0.082	0.046
4	Polyphenols (g/100g dry wt)	0.412	0.468
5	DNA (mg/g)	0.181	0.165
6	RNA (mg/g)	0.057	0.065
7	Ash (%)	9.5	9.83

Table 2. Mineral Analysis of Healthy and Infected Roots of Soybean by *F. oxysporum*

Sr. No.	Estimation	Healthy Soybean root	Infected Soybean root
1	Moisture (%)	1.55	1.51
2	Phosphorus (%)	0.04	0.04
3	Potassium (%)	0.11	0.096
4	Calcium (%)	1.22	1.16
5	Magnesium (%)	2.74	2.69
6	Sulphur (%)	0.63	0.52
7	Sodium (%)	2.47	1.94
8	Zinc (ppm)	53.52	47.9
9	Ferrous (ppm)	55.86	53.78
10	Copper (ppm)	30..10	29.82
11	Manganese (ppm)	74.26	71.78
12	Molybdenum (ppm)	2.35	2.29
13	Nitrogen (%)	2.49	2.36
14	Boron (ppm)	11.66	11.59

Table 3. Biochemical Analysis of Healthy and Infected Roots of Soybean by *F. solani*

Sr. No.	Estimation	Healthy Soybean root	Infected Soybean root
1	Starch (g/100g dry wt)	1.72	1.59
2	Reducing sugar (g/ 100g dry	0.22	0.173
3	Total sugar (g/100g dry wt)	0.123	0.067
4	Polyphenols (g/100g dry wt)	0.47	0.528
5	DNA (mg/g)	0.192	0.179
6	RNA (mg/g)	0.068	0.082
7	Ash (%)	9.8	10.2

Table 4. Mineral Analysis of Healthy and Infected Roots of Soybean by *F. solani*

Sr. No.	Estimation	Healthy Soybean root	Infected Soybean root
1	Moisture (%)	1.65	1.59
2	Phosphorus (%)	0.06	0.05
3	Potassium (%)	0.13	0.098
4	Calcium (%)	1.32	1.24
5	Magnesium (%)	2.84	2.79
6	Sulphur (%)	0.69	0.59
7	Sodium (%)	2.67	2.15
8	Nitrogen (%)	2.62	2.46
9	Ferrous (ppm)	57.49	56.1
10	Copper (ppm)	30.36	29.95
11	Manganese (ppm)	74.82	71.93
12	Molybdenum (ppm)	2.76	2.59
13	Zinc (ppm)	53.69	49.4
14	Boron (ppm)	12.24	12.13

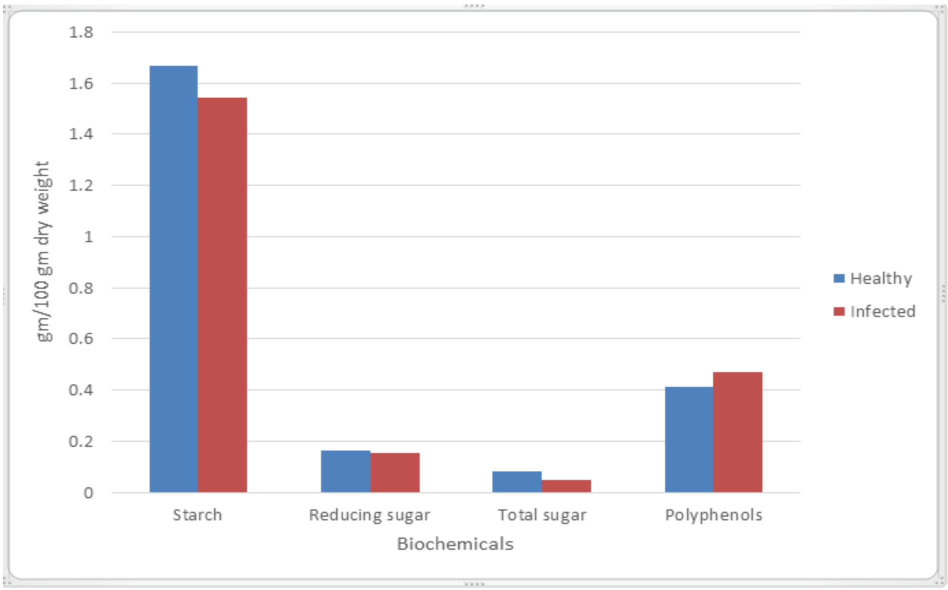

Fig. 1. Biochemical Profile of Healthy and Infected Roots of Soybean by *F. oxysporum*

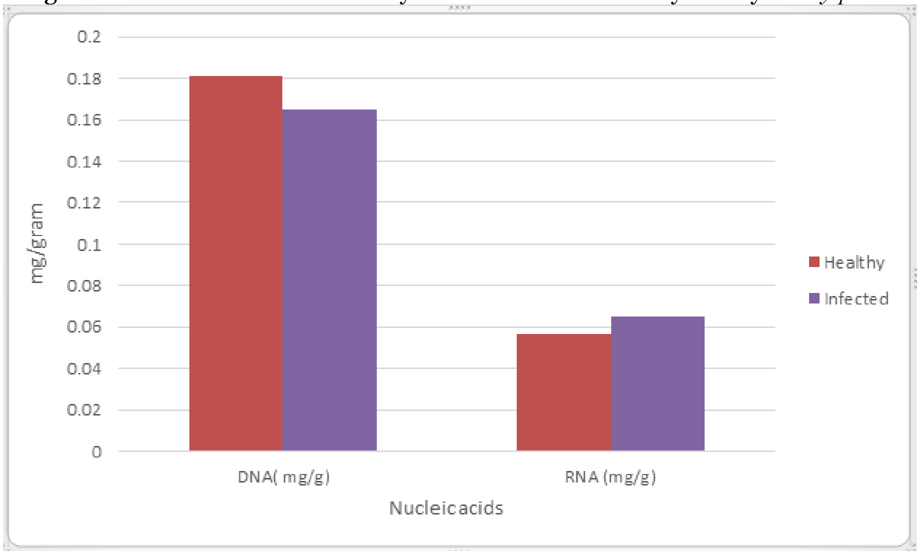

Fig. 2. Nucleic acid Profile of Healthy and Infected Roots of Soybean by *F. oxysporum*

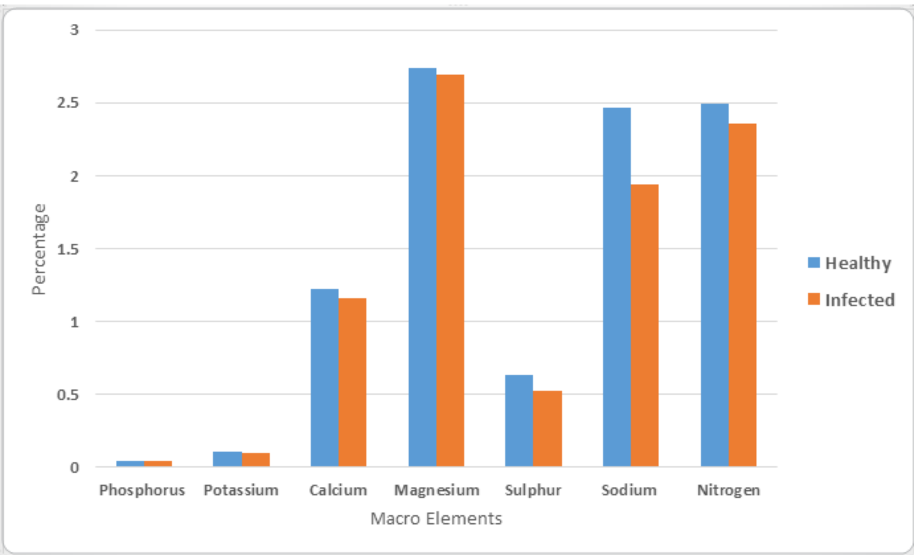

Fig. 3. Macro Elements Profile of Healthy and Infected Roots of Soybean by *F. oxysporum*

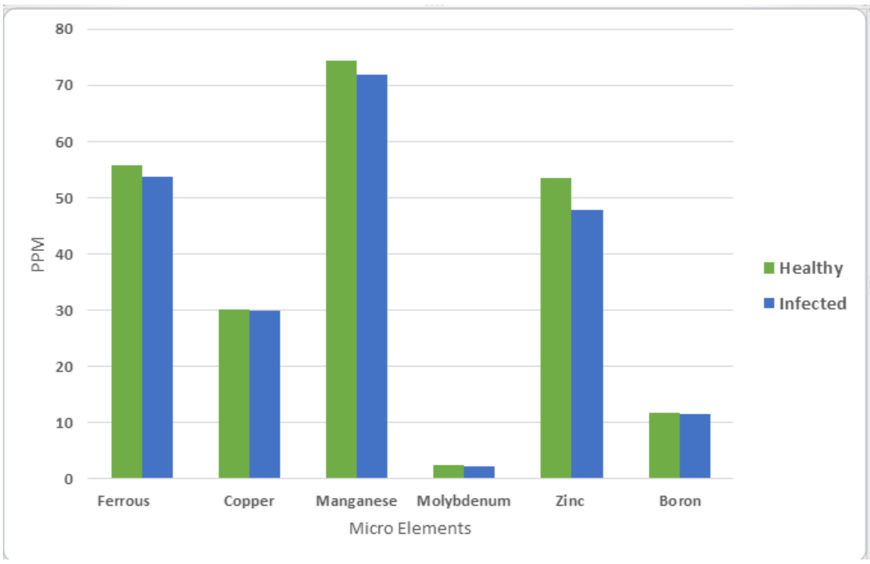

Fig. 4. Micro Elements Profile of Healthy and Infected Roots of Soybean by *F. oxysporum*

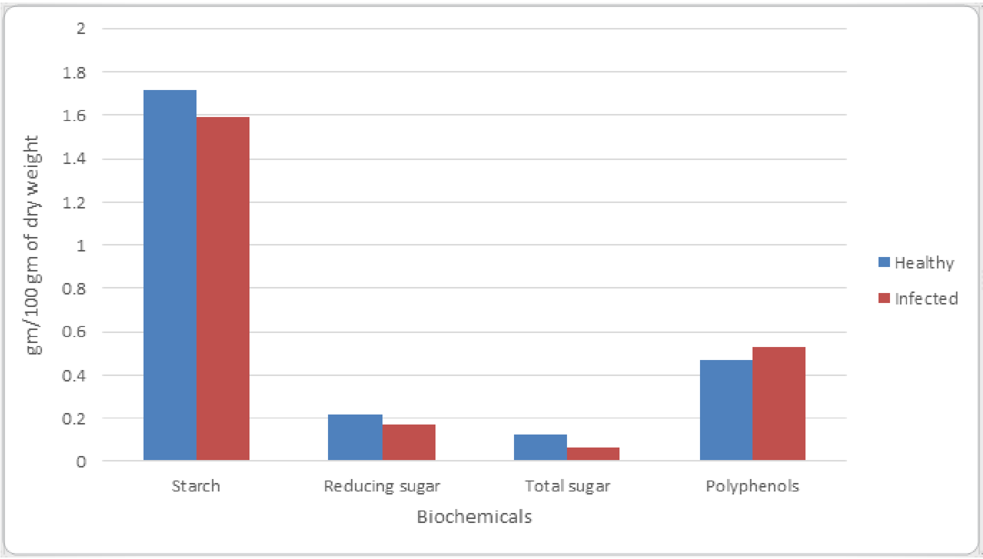

Fig. 5. Biochemical Profile of Healthy and Infected Roots of Soybean by *F. solani*

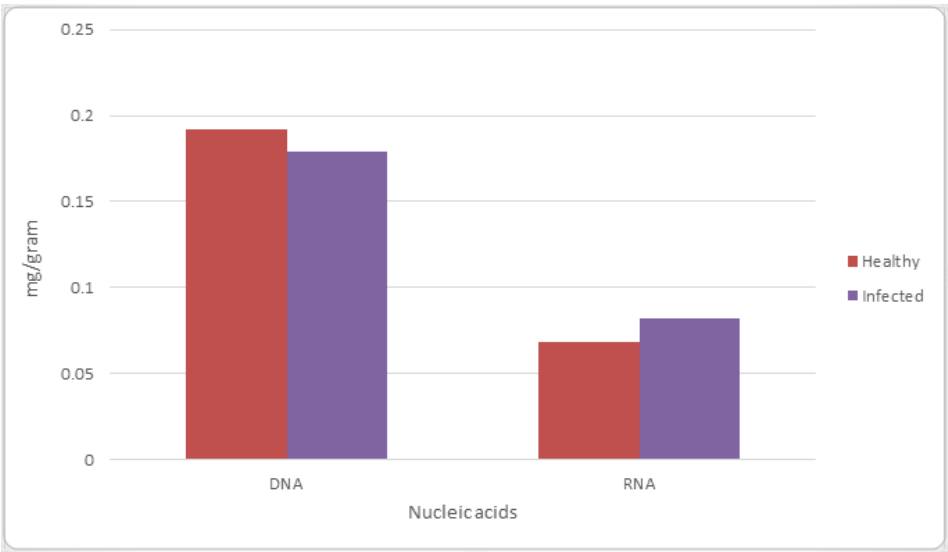

Fig. 6. Nucleic acid Profile of Healthy and Infected Roots of Soybean by *F. solani*

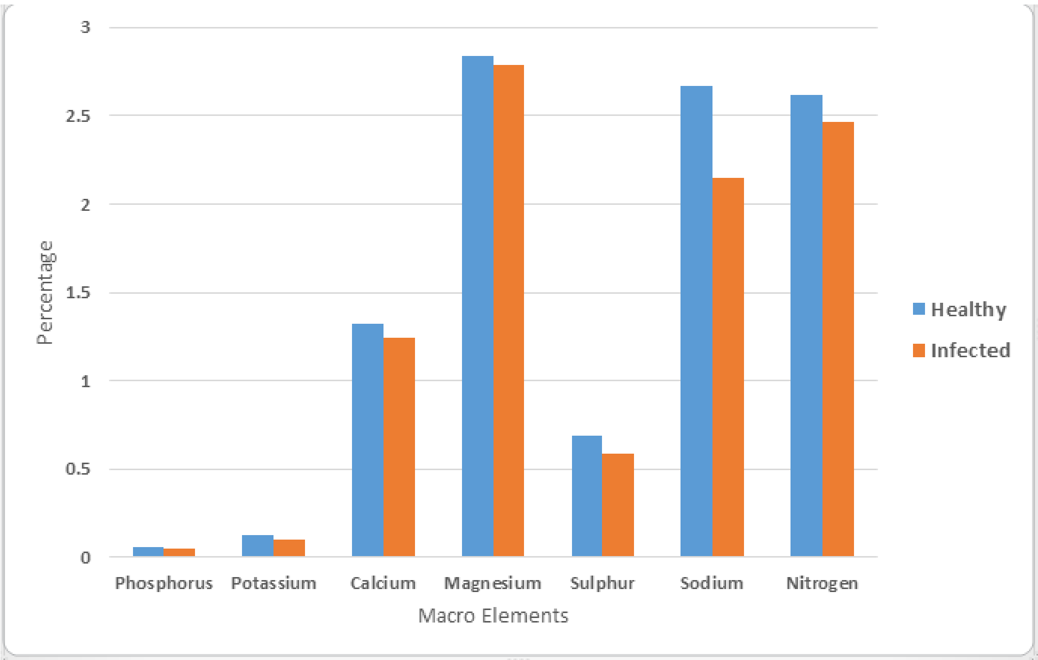

Fig. 7. Macro Elements Profile of Healthy and Infected Roots of Soybean by *F. solani*

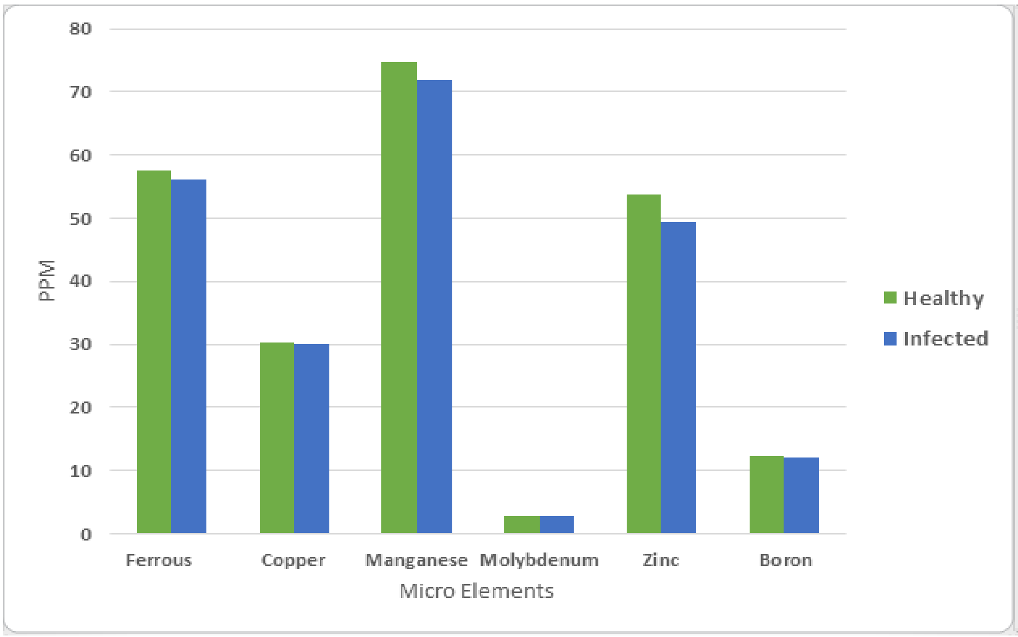

Fig. 8. Micro Elements Profile of Healthy and Infected Roots of Soybean by *F. solani*

Acknowledgment
The authors express their sincere gratitude to the Research Centre, Department of Botany, Tuljaram Chaturchand College, Baramati, for providing the necessary laboratory facilities and institutional support to carry out the present investigation.

Financial support and sponsorship
Nil.

Conflicts of interest
The authors declare that there are no conflicts of interest regarding the publication of this paper.

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