Print ISSN: 0976-2876 Online ISSN: 2250-0138

Available online at: http://www.ijsr.in

INDIAN JOURNAL OF SCIENTIFIC RESEARCH

DOI:10.32606/IJSR.V17.I1.00005

Received: 17-05-2026 Accepted: 27-07-2026 Publication: 31-08-2026

Indian J.Sci.Res. 17 (1): 31-37, 2026 Original Research Article

EVALUATION OF THE GERMINATION AND MORPHOLOGY OF *Abelmoschus esculentus* (OKRA) UNDER THE STRESS OF NICKEL NITRATE

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ABSTRACT

The present study investigated the toxicological effects of nickel nitrate on the growth and development of *Abelmoschus esculentus* (var. Kashi Chaman, VRO-109) across M_1 and M_2 generations under field conditions. Seeds were exposed to different concentrations of nickel nitrate (0.125%, 0.250%, 0.375% and 0.500%), and key morphological parameters including germination, seedling survival, plant height and number of branches were evaluated. A concentration-dependent decline in germination and survival was observed, indicating the toxic impact of nickel stress. Higher concentrations significantly reduced plant height and branching in the M_1 generation. Similar trends were recorded in the M_2 generation. Although the extent of reduction was comparatively lower, suggesting development of adaptation or tolerance in the subsequent generation. Control plants consistently exhibited better performance across all measured traits. The findings demonstrate that elevated nickel levels adversely affect vegetative growth and developmental processes in okra, likely due to disruption of physiological and metabolic functions. However, the improved response in the M_2 generation highlights the potential for adaptive mechanisms under continued stress. This study provides valuable insights into plant responses to nickel stress and supports the development of tolerant crop varieties for contaminated environments.

KEYWORDS: Nickel Nitrate, *Abelmoschus esculentus*, Germination, Morphology, M_1 and M_2 Generations

Vegetables, being a rich and cheap source of vitamins and minerals, occupy an important place in the food basket of Indian consumers. Therefore, it occupies a significant place in the human diet because its vitamins and minerals are essential for human health and growth.

Okra (Bhindi or lady's finger) is an important summer and rainy season vegetable crop which is rich in carbohydrates, protein and Vitamin C. The essential and non-essential amino acids that okra contains are comparable to those of soybean, which is a vital part of the human diet.

Okra is one of the world's oldest cultivated crops. It can be grown in many parts of the world, especially in tropical and sub-tropical countries (Gupta & Patra, 2021).

Due to its high content of vitamins, minerals and fibre, okra is price for its nutritional make up. It has a high concentration of magnesium, folate, vitamin K and vitamin C. The use of okra is growing worldwide due to its growing appeal as a nutritious and adaptable vegetable that may be roasted, fried or added to stews and curries (Elkhalifa *et al*., 2021).

Abelmoschus esculentus (okra) is a widely cultivated vegetable crop that serves as an important component of the diet in many tropical and subtropical regions. It is valued for its high nutritional content, providing essential vitamins, minerals, dietary fibre and bioactive compounds that contribute to human health (Ramteke *et al*., 2016; Zhou *et al*., 2016). However, like many vegetable crops, okra has the ability to accumulate both essential and non-essential heavy metals from contaminated soils and irrigation water, which may pose potential health risks to consumers (Waqas *et al*., 2014).

Heavy metal pollution has emerged as a major environmental concern due to rapid industrialization, urbanization and agricultural intensification. Among various heavy metals, nickel (Ni) is considered an essential micronutrient for plants at trace levels however, at higher concentrations, it becomes toxic and adversely affects plant growth, development and productivity. Nickel toxicity interferes with several physiological and biochemical processes, including seed germination, enzyme activity, photosynthesis and nutrient uptake (Seregin & Kozhevnikova, 2006).

Increased metal concentration causes oxidative stress and membrane damage, leading to reduced survival (Sharma & Dubey, 2005).

Abelmoschus esculentus (okra) is an economically important vegetable crop widely cultivated in tropical and subtropical regions including India. It serves as a rich source of vitamins, minerals and dietary fibre. Due to its agricultural importance and sensitivity to environmental stress, okra is frequently used as a model

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crop to study the effects of abiotic stress factors including heavy metal toxicity. Previous studies have reported that heavy metals such as cadmium, lead and nickel significantly reduce germination percentage, plant height, biomass, and yield attributes in okra and other crop plants (Sharma *et al*., 2008; Gupta *et al*., 2013).

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Sharma and Dubey (2005) reviewed the phytotoxic effects of lead on plants and reported that excessive Pb accumulation disrupts normal physiological and biochemical processes. Lead-induced toxicity promotes the generation of reactive oxygen species (ROS), resulting in oxidative stress, lipid peroxidation, membrane damage, and reduced plant growth. The review further highlighted that plants activate antioxidant defence mechanisms to mitigate oxidative damage; however, prolonged exposure adversely affects plant survival and productivity.

Interestingly, some studies have reported a stimulatory effect at lower concentrations of heavy metals, a phenomenon known as hormesis, where low doses may enhance certain growth parameters while higher doses exert toxic effects (Rizwan *et al*., 2017). However, the extent of these effects varies depending on plant species, genotype, and concentration of the metal applied.

Buts *et al*., (2013) also reported the harmful effect of $CdCl_2$ on *Lens esculentus*. They treated its seeds with varying concentrations of cadmium chloride for up to two generations. They found that toxic effect increases with increase in the treatment concentration in both generations on all vegetative growth parameters and productivity but the losses incurred were recovered slightly in 2nd generation in lower treatment concentration. Among plants in 0.5% treatment concentration, productivity declined more than 50%.

Despite considerable research on heavy metal toxicity, limited information is available on the mutagenic and physiological effects of nickel nitrate on different generations (M_1 and M_2) of okra, particularly in the variety Kashi Chaman (VRO-109). Understanding these effects is crucial for evaluating the tolerance level of crops and their potential adaptability under metal-stressed conditions.

Therefore, the present investigation was undertaken to assess the effect of different concentrations of nickel nitrate on seed germination, seedling survival, plant height and no. of branching in *Abelmoschus esculentus* var. Kashi Chaman (VRO-109) across M_1 and M_2 generations. The study aims to provide insights into the dose-dependent response of okra to nickel stress and its implications for crop productivity and environmental risk assessment.

MATERIALS AND METHODS

Okra is an important member of the family Malvaceae with 2n=8x=72 to 144 chromosomes and is polyploid in nature. The seeds of *Abelmoschus esculentus* were procured from ICAR-IIVR, Varanasi, Uttar Pradesh. Heavy metal Nickel nitrate is used to evaluate the toxic effects in vivo on the variety of okra Kashi Chaman. The treatment concentrations are 0.125%, 0.250%, 0.375% and 0.500% of nickel nitrate used as heavy metal.

Healthy seeds of equal size & shape were selected for treatment with Nickel nitrate. Before sowing of seeds in the experimental plots, seeds were soaked overnight in distilled water. Then soaked 100 seeds were placed in each petri-dishes containing concentration of 0.125%, 0.250%, 0.375% and 0.500% of Nickel nitrate for 04 hours in the laboratory and after treatment these seeds were allowed to germinate in petri-dishes lined with filter paper and cotton wools. After radicle emergence, they were sown in experimental field under controlled conditions. 100 seeds soaked in distilled water for overnight were sown in experimental field as control. The seeds were shown in lines keeping a distance between rows is 75-80 cm. Rows in east-west direction that will best capture the sunlight.

On the contrary, in the field, the emergence of hypocotyls and cotyledons above the surface of the soil had been taken as an index of germination. Arrangement was made for regular weeding operation and irrigation. Neither chemical nor other fertilizers were used. This was done to avoid confusion. In the field, seeds were shown in the last week of February and final harvesting was done during the period of September. In between the above periods morphological characters were studied with respect to plant height and number of branches per plants etc.

The seeds were collected after harvesting and stored in glass containers separately with specific symbols & considered as M_1 generation. Weight of hundred seeds was taken separately obtained from control as well as treated plants and seed quality was also observed. The stored seeds of M_1 generation were again treated with the corresponding concentration i.e. 0.125%, 0.250 %, 0.375 % and 0.500% of nickel nitrate for study by the same methods as mentioned above for M_1 generation and sown in the prepared field. Now this second generation was considered as M_2 generation. The morphological characters were observed like M_1 generation. The phenotypic variability and their frequencies were collected & finally the rate of induced variability of quantitative characters is calculated.

RESULTS AND DISCUSSION

The results of this investigation are shown in Tables 01 & 02 and Fig. 01-04. The details are as below:

Effect of Nickel Nitrate on seed germination

Out of 100 seeds 86, 82, 78 & 67 in 0.125%, 0.250%, 0.375% & 0.500% treatment concentrations of nickel nitrate while in control 95 seeds are germinated in M_1 generation.

Out of 100 seeds 86, 81, 76 & 65 in 0.125%, 0.250%, 0.375% & 0.500% treatment concentrations of Nickel nitrate while in control 96 seeds are germinated in M_2 generation. (Fig.01)

Therefore, the data clearly show that Nickel nitrate adversely affects the seed germination in both generations of Kashi Chaman. As the concentration of nickel nitrate increases, the rate of seed germination decreases gradually, demonstrating an inverse relationship between germination rate and treatment concentration. This finding is similar to the finding of Buts *et al.*, 2011 in *Lens esculentus* under the stress of Lead nitrate.

Effect of Nickel nitrate on seedling survival

The seedling survival percentage of M_1 generation for variety Kashi Chaman (VRO-109) was found to be 80, 76, 69 and 52 for concentration levels of 0.125%, 0.250%, 0.375% and 0.500% respectively, whereas the survival percentage in control was found to be 93.

In case of M_2 generation, the survival percentage were found to be 80, 75, 66 & 49 in 0.125%, 0.250%, 0.375%, & 0.500% treatment concentrations respectively, whereas the survival percentage in control was found to be 95. (Fig.02)

This demonstrates that as the concentration of nickel nitrate increases, the seedling survival percentage decreases. The reduction was a minor at lower concentrations in comparison to the control; however, the reduction was significant at high concentrations for both generations of Kashi Chaman.

Heavy metals disrupt enzyme activity and water uptake, reducing germination efficiency (Sethy and Ghosh, 2013).

Effect of Nickel nitrate on Plant height

The height of the plants was determined when they reached maturity in each treatment group. The measurement starts from the soil surface to the top end of the peduncle, with measurements taken in meters.

In the case of M_1 generation, the average height of Kashi Chaman (VRO-109) variety is recorded as 109.722 cm, 105.866 cm, 95.667 cm and 82.916 cm at 0.125%, 0.250%, 0.375% and 0.5% levels of nickel nitrate respectively, whereas 108.916 cm was recorded under control.

In the case of M_2 generation, the height of Kashi Chaman (VRO-109) variety is recorded as 108.5cm, 104.32cm, 98.29cm and 91.34cm at 0.125%, 0.250%, 0.375% & 0.5% treatment concentration respectively, whereas 110.60cm was recorded under control.

There is an increase in the mean height of plants under the treatment of 0.125% where the average height is 109.72cm. The average height of all treated plant decreased as increasing the treatment concentration in the M_1 and M_2 generation. The greatest reduction in height obtained when the treatment concentration is 0.500%. (Fig.03)

Effect of Nickel nitrate on Number of branches

Average number of branches in variety Kashi Chaman in M_1 generation were 2.10, 1.916, 1.214 & 0.916 in case of 0.125%, 0.250%, 0.375% & 0.500% treatment concentration of Nickel nitrate respectively in comparison to 2.416 in control.

Similarly, in M_2 generation the value for the same concentration were 1.695, 1.352,1.32 & 0.708 respectively in comparison to 2.697 in control. (Fig.04)

Thus, it can be concluded that there is an induced effect of nickel nitrate on emergence of branches in both the generations up to 0.250% however 0.375% & 0.500% treatment concentration may do not induce one or two branching in few plants. Hence induction of branching reduced with increasing the treatment concentration.

Table 1: Morphological parameters of *Abelmoschus Esculentus* (Kashi Chaman- VRO-109) under the stress Of Nickel Nitrate in M_1 Generation

Treatment (Nickel Nitrate)	Germination of seeds in the field (Out of 100)	Seedling survival in the field (Out of 100)	Average Height of plant(cm) + SD	No. of Branches per plant ±SD
0.125%	86	80	109.722±11.001	2.1±0.594
0.250%	82	76	105.866±8.374	1.916±0.425
0.375%	78	69	95.667±6.568	1.214±0.446
0.500%	67	52	82.916±6.141	0.916±0.688
CONTROL	95	93	108.916±8.010	2.416±0.464

Table 2: Morphological parameters of *Abelmoschus Esculentus* (Kashi Chaman- VRO-109) under the stress Of Nickel Nitrate in M_2 Generation

Treatment (Nickel Nitrate)	Germination of seeds in the field (Out of 100)	Seedling survival in the field (Out of 100)	Average Height of plant(cm) + SD	No. of Branches per plant ±SD
0.125%	86	80	108.5±16.920	1.695±1.362
0.250%	81	75	104.32±15.986	1.352±1.432
0.375%	76	66	98.291±13.347	1.320±1.547
0.500%	65	49	91.347±13.251	0.708±1.041
CONTROL	96	95	110.604±14.182	2.697±1.472

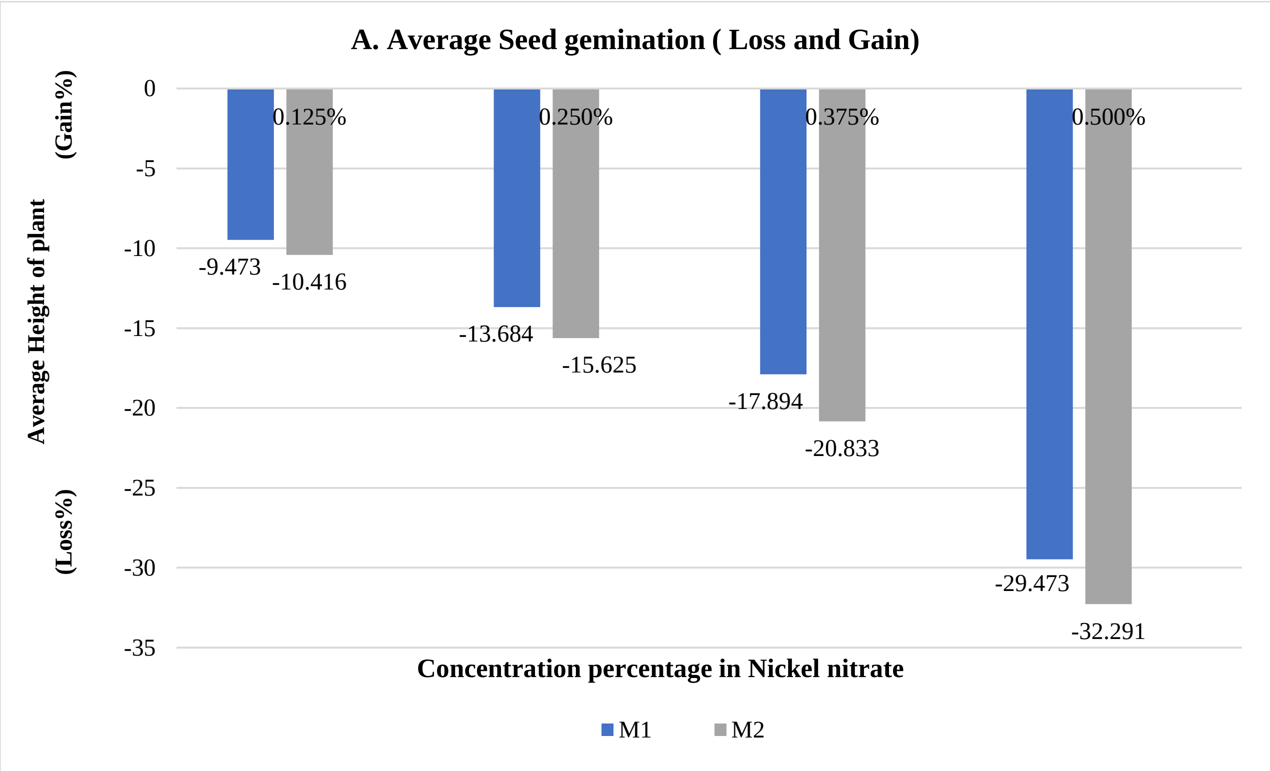

Figure 1: Percentage variation in seed germination of *Abelmoschus Esculentus* (Kashi Chaman- VRO-109) treated with Nickel Nitrate in respect to control in M_1 and M_2 generation.

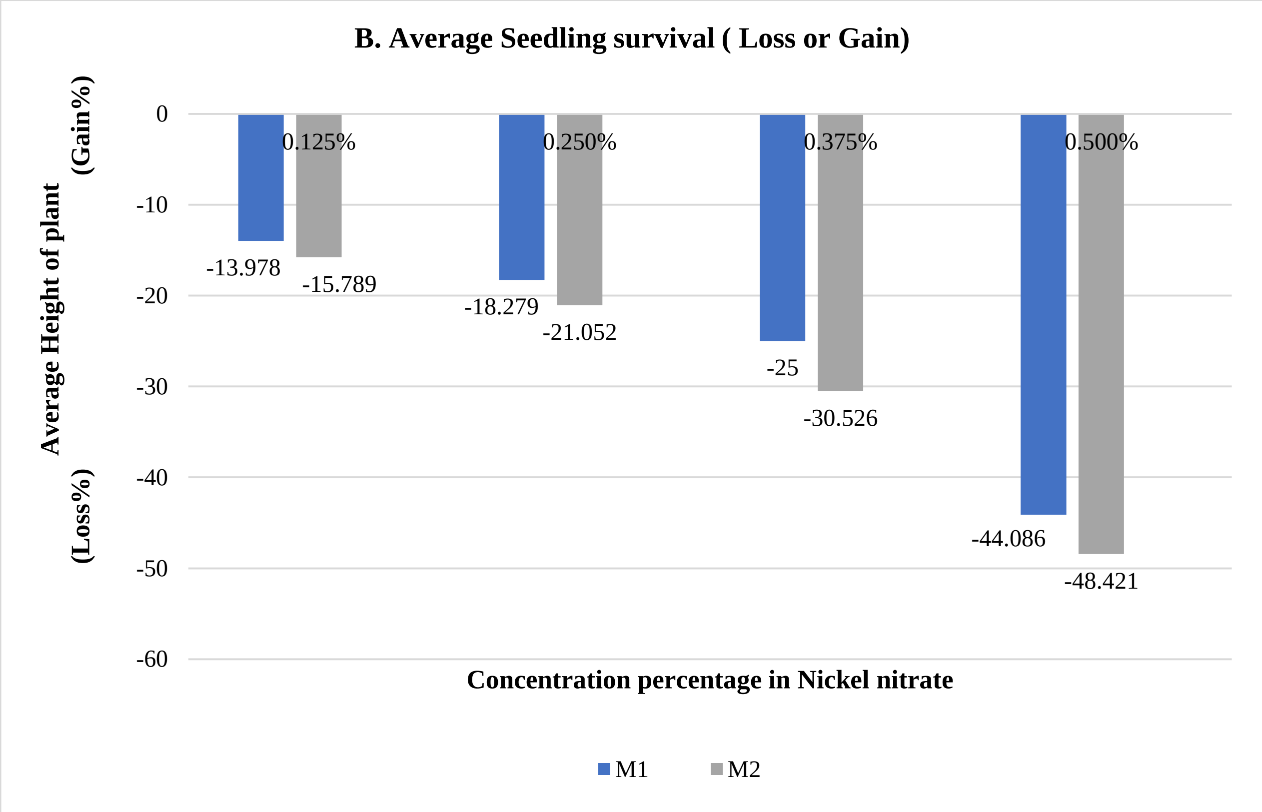

Figure 2: Percentage variation in seedling survival of *Abelmoschus Esculentus* (Kashi Chaman- VRO-109) treated with Nickel Nitrate in respect to control in M_1 and M_2 generation.

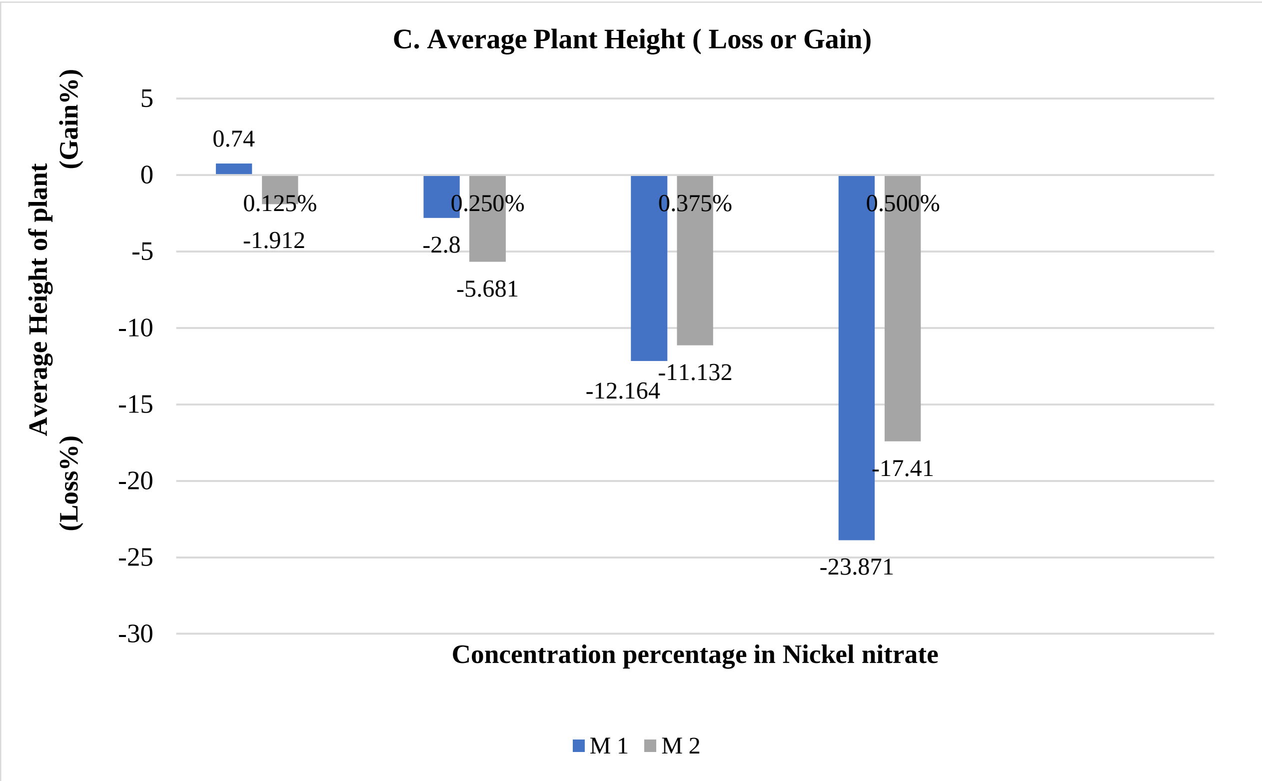

Figure 3: Percentage variation in plant height of *Abelmoschus Esculentus* (Kashi Chaman- VRO-109) treated with Nickel Nitrate in respect to control in M_1 and M_2 generation.

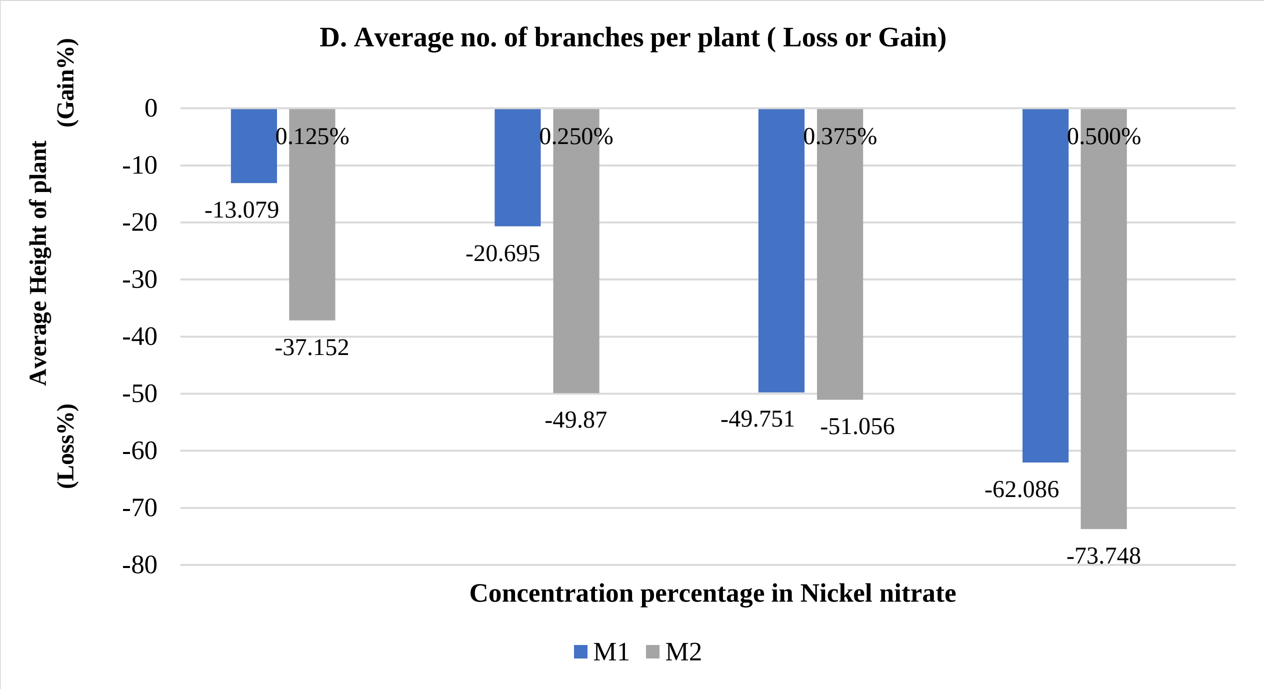

Figure 4: Percentage variation in number of branches of *Abelmoschus Esculentus* (Kashi Chaman- VRO-109) treated with Nickel Nitrate in respect to control in M_1 and M_2 generation.

CONCLUSION

The present study concludes that nickel nitrate has a dose-dependent inhibitory effect on the morphological and developmental parameters of *Abelmoschus esculentus*. Higher concentrations (0.375% and 0.500%) significantly reduced germination, seedling survival, plant height, and branching. The M_2 generation showed partial tolerance, suggesting potential adaptive responses or selection effects. Overall, the study highlights that nickel nitrate toxicity adversely affects seed germination, crop growth and its accumulation in agricultural soils can pose serious risks to plant health. However, the observed tolerance in later generations may provide a basis for developing metal-tolerant varieties through selection and breeding strategies.

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