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Role of Groundwater from Different Localities of Rohtak city on the growth and development of *Solanum melongena* plant.

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Abstract
Water plays a vital role in the growth and development of plants. It is an essential component of the plant's internal structure, serving as a key medium for various biochemical reactions. The physicochemical properties of water make it uniquely suited for sustaining plant life. Fresh water can be contaminated by various contaminants such as, heavy metals, and excessive minerals leading to salinity. The contaminants of water may cause pH Imbalance in the water leading to several ill-effects. For sustainable agriculture, natural ecosystems, and guaranteeing food security for a growing global population. Brinjal (*Solanum melongena*) is consumed daily throughout the Indian subcontinent as a vegetable throughout the year. Average brinjal production in the year 2015 to 2021, was apx. 12.98 million metric tons grown over 750 thousand hectares of agricultural land. Tap-water supplied by local Municipal Corporation is mainly used for irrigation of kitchen garden. Ground water, mainly obtained from a hand pump in vicinity is also used in some cases. Ground water may vary in different water tables that changes from area-to-area and may also vary with the depth. Draught resistant (HyVeg™) Nano brinjal seeds were sown in water samples (i) tap water (control); (ii) Sector 3; (iii) Sector 27; and (iv) Tilyar Lake. The germinated seeds upon leaves formation were transferred to the small pots in nursery. Successfully germinated plantlets were transferred to four different pots filled in with sterile soil supplemented with organic cow dung manure. The pots were watered routinely with the water from these ponds with the control tap water and the three hand pumps located at Sector 3; sector 27, and Tilyar Lake in Rohtak city. The plants were raised to the fruit bearing stage. The germination and the plant growth data were statistically tested and analyzed to gain an insight into the effect of different water sources as well as different soil on brinjal plant growth and yield.

Introduction

Water plays a vital role in the growth and development of plants (Brendel, 2021). It is an essential component of the plant's internal structure, serving as a key medium for various biochemical reactions. The quality of water plays a significant role in determining the optimum growth of plants (Brendel, 2021). It is important to note that different plants may have specific tolerances and preferences for water quality. Some plant species are more adaptable and can tolerate a wider range of water conditions. Understanding the water requirements of the specific plants being grown and regularly monitoring and adjusting water quality parameters can contribute to optimal plant growth and overall health (Akinci et al., 2010; 2013).

Rohtak district area falls in Yamuna sub-basin of Ganga basin, and is mainly drained by the artificial drain No. 8. Water from the Bhalaut sub-branch of the sub-basin is used for irrigation in the Rohtak block of the district (CGWB, 2013). Riverine water usually have very high heavy metal content. Average lead, for instance, ranged from 3 to 30 parts per billion in a river (Palisoc et al., 2021), which is much higher than the limit set by World Health Organization (World Health Organization, 2017). Water treatment plants are in place to treat the riverine water for municipal supply in a city.

The physicochemical properties of water make it uniquely suited for sustaining plant life. Its polarity allows it to dissolve and transport mineral nutrients from the soil to various plant organs. The continuous use of brackish groundwater for irrigation has led to increased soil alkalinity and salinity in the region. This causes soil deterioration, making it difficult for nutrient uptake by the brinjal plants. While brinjal is relatively more tolerant to salinity than some other vegetable crops (withstanding electrical conductivity, EC, up to 10 dS/m before experiencing 50% yield reduction (Phogat et al., 2010), the severe quality issues in certain parts of Rohtak can still significantly hamper growth and reduce, or in extreme cases, destroy, the yield (Manchanda, 1976; Phogat et al., 2010). Five percent of the groundwater quality of the district Rohtak was ranked as good; 14 % was ranked marginal; 22% was saline; 15% was alkali, and the rest 44% was saline-alkali (Manchanda, 1976).

Fresh water can be contaminated by various contaminants such as, heavy metals, and excessive minerals leading to salinity. The contaminants of water may cause pH Imbalance in the water leading to several ill-effects. Contamination of lead in the irrigation water caused deformations in the roots of tomato and eggplant (Gautam et al., 2011). Contaminants in natural water sources can have negative impacts on growth of plants. Several heavy metals such as lead, cadmium, and mercury are toxic to plants, even at low concentrations (Briffa et al., 2020). Bio-accumulation of these heavy metals in the plant tissues may interfere with essential metabolic processes and enzyme activities resulting in stunted growth, chlorosis (yellowing of leaves), reduced photosynthesis, and even plant death. However, a few of these metals possess some of the metabolic importance of biota (essential metals) and become toxic or poisonous at higher concentrations (Cu, Fe, Zn, Mn, and Ni) (Rai et al., 2019).

For sustainable agriculture, natural ecosystems, and guaranteeing food security for a growing global population, it is crucial to maintain a diversified and balanced soil biota community. The soil biota is crucial for robust and productive ecosystem leading to optimum plant growth. The diverse community of micro- and macro-organisms that live in the soil environment is referred to as the soil biota. These species engage in a variety of interactions with plants and one another, which affects plant development and the dynamics of the entire ecosystem.

Brinjal (*Solanum melongena*) is consumed daily throughout the Indian subcontinent as a vegetable throughout the year. Average brinjal production in the year 2015 to 2021, was apx. 12.98 million metric tons grown over 750 thousand hectares of agricultural land (Minhas, 2022). Brinjal is rich in vitamins, minerals, and phenolic compounds (Naeem and Ugur, 2019). Brinjal is prone to metal accumulation (Samal et al., 2011; Islam et al., 2014; Bushra et al., 2022).

Tap-water supplied by local Municipal Corporation is mainly used for irrigation of kitchen garden. Ground water, mainly obtained from a hand pump in vicinity is also used in some cases. Ground water may vary in different water tables that changes from area-to-area and may also vary with the depth (Figure 1). Nearly 98 % of the Rohtak District has water table within 10 meters from the ground surface (CGWB, 2013; Kumar et al., 2013).

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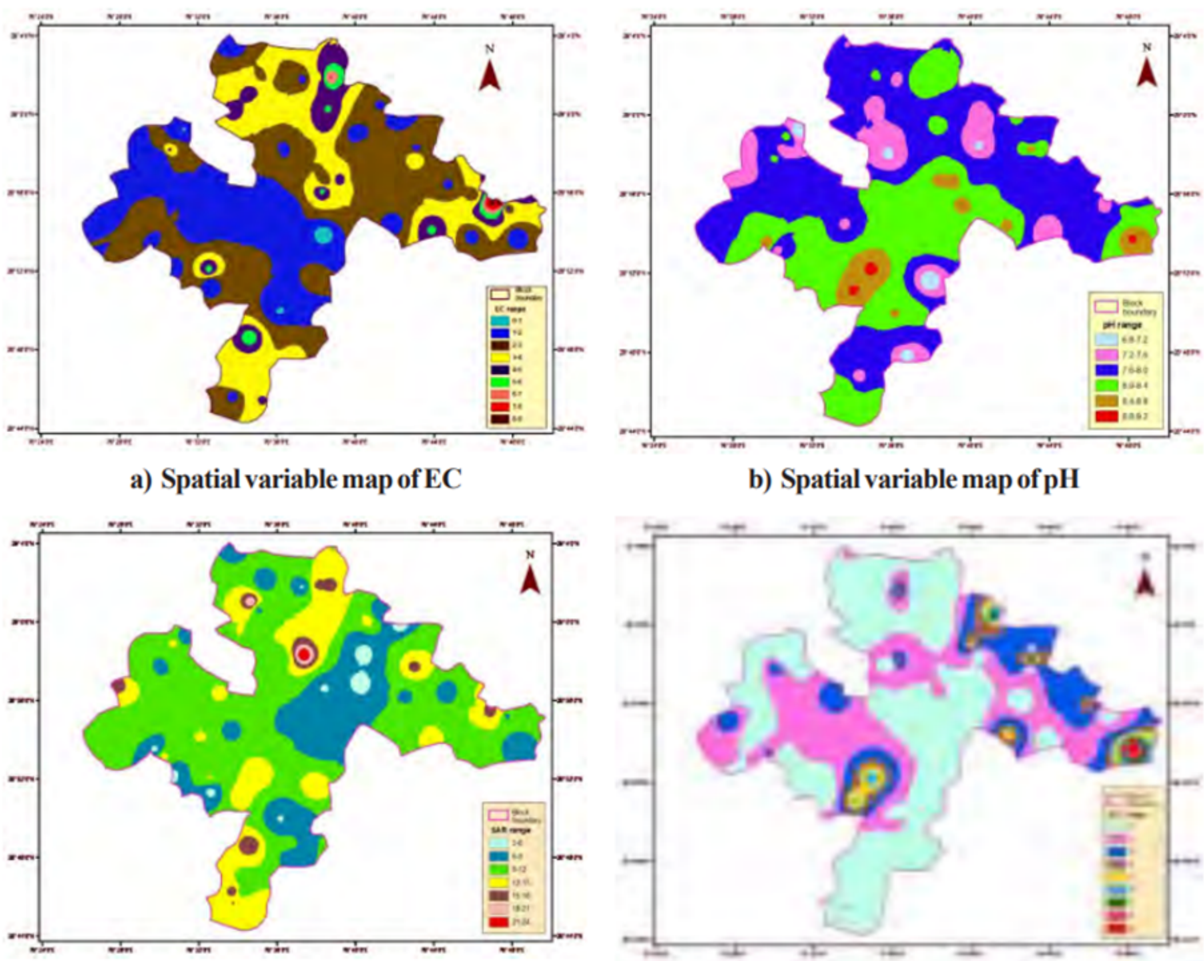
Figure 1. Spatial variable map of water quality parameters (EC, pH, SAR, RSC) of groundwater in Rohtak block of Rohtak district (Kumar et al., 2013).



a) Spatial variable map of EC **b) Spatial variable map of pH**

c) Spatial variable map of SAR **d) Spatial variable map of RSC**

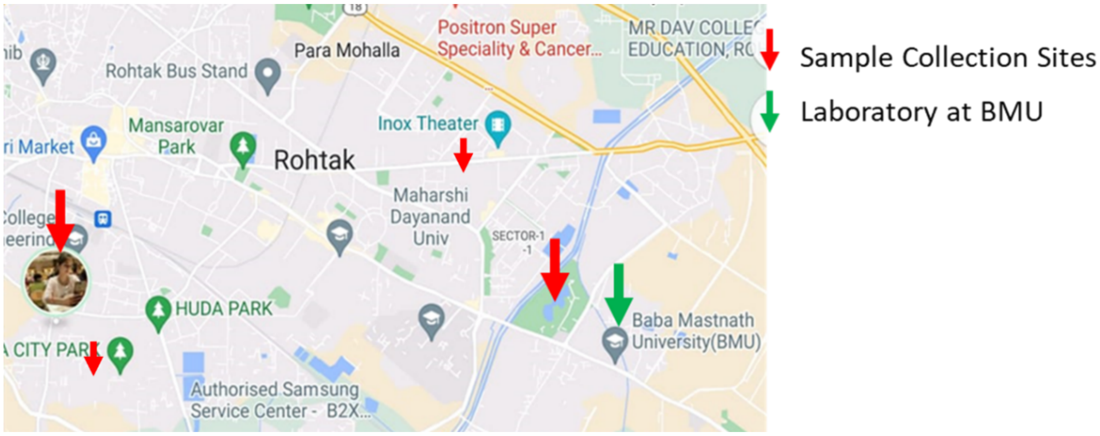
To ensure optimal brinjal plant growth, it is essential to monitor and manage water quality by minimizing pollution sources, employing water treatment methods if necessary, and choosing appropriate water sources for irrigation. Regular soil and water testing can help identify contaminants and take corrective measures to maintain a healthy environment for floral growth. The present study is thus designed to study the impact on the plant growth irrigated with the groundwater extracted using different hand pumps located at various sites in Rohtak.

Materials and Methods

Groundwater sample collection

Water sample was collected from three different sites from i.e., Sector 3 (Lat. 28.896921, Long. 76.625218), Sector 27 (Lat. 28.862423, Long. 76.649782), and Tilyar Lake (Lat. 28.880222, Long. 76.634892) of the Rohak city, Haryana (Figure 2).

Figure 2. Map showing sample collection sites (Sector 27, Sector 3, and Tilyar Lake, Rohtak) and laboratory at Baba Mastnath University, Asthal Bohar, Rohtak.



Seed Selection

The brinjal seed (HyVeg™ Nano) were draught resistant, thus, selected to sow in the study (Figure 3).

Seed Germination

Four new sterile disposable petri dishes were lined with filter papers. 35 draught resistant Nano brinjal seeds were placed in each petri dishes well-labelled with permanent marker pen, as (i) control--> tap water; (ii) Sector 3; (iii) Sector 27; and (iv) Tilyar Lake. The four water samples collected were overlaid by the 4 samples, labelled accordingly (Figure 4).

Figure 3. Nano Brinjal Seeds, Purple Variety, Transforming Genetics

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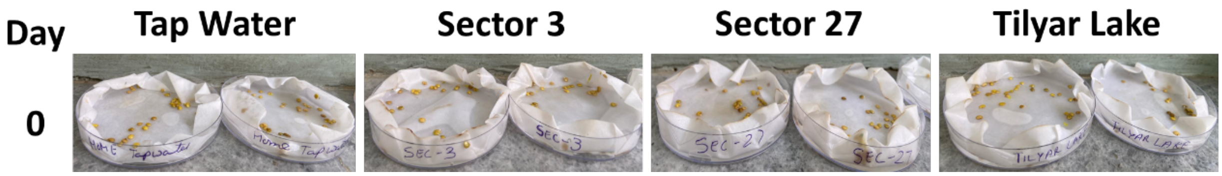
Figure 4. Setup for brinjal seed germination in laboratory.



Pot Experiments

The germinated seeds upon leaves formation were transferred to the small pots in nursery (figure 11). Successfully germinated plantlets were transferred to four different pots (Dimensions, i.e., the volume of the pots) filled in with sterile soil supplemented with organic cow dung manure. The pots were watered routinely with the water from these ponds with the control tap water and the three hand pumps located at Sector 3; sector 27, and Tilyar Lake in Rohtak city. The plants were raised to the fruit bearing stage (Figure 12).

Effect of water on the plant growth

Brinjal plants (*Solanum melongena*) Hy Veg Nano seeds was sown in pots, prefilled with sterile soil supplemented with cow dung manure.

The plantlets were irrigated with different groundwater samples viz., from hand pump located in Sector 3; Sector 27 and Tilyar Lake taking tap water as a control. The plants thus watered were monitored regularly for their growth and yield.

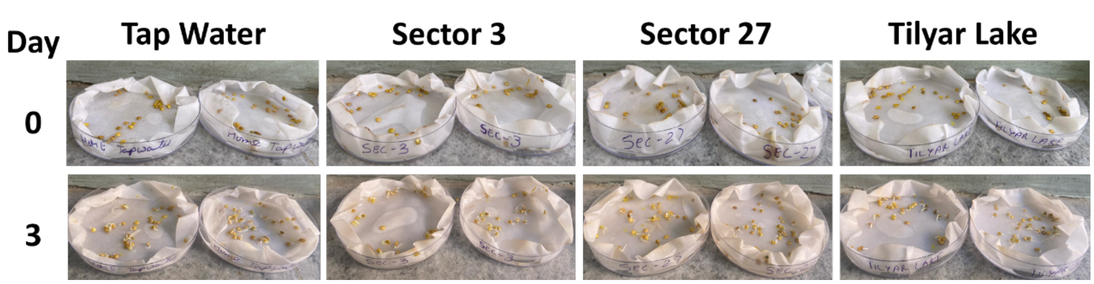
The growth parameters including, Seed Germination, Fresh & Dry weight of Shoots as well as the Roots, and Shoot and Root length

Seed germination

HyVeg™ nano variety seeds (N= 35 each) were germinated in neatly labelled filter paper lined petri dishes as described in the Materials and Methods (See section 3.3.2.). 33 ± 1.65 germinated when watered with the control tap water. However, 34.5 ± 1.73 seeds were germinated when watered with the groundwater from sector 3. Similarly, watering with the groundwater from sector 27 resulted 27.5 ± 1.29 seeds. Whereas, 33 ± 1.65 germinated when watered with the groundwater from Tilyar Lake (Figure 5 and 6).

Statistical analysis using student's T test revealed that the differences in the germination due to sector 27 watering was significant with p value<0.05 than the control. On the other hand, the differences in the germination due to watering from the groundwater from Sector 3 as well as from Tilyar Lake was non-significant.

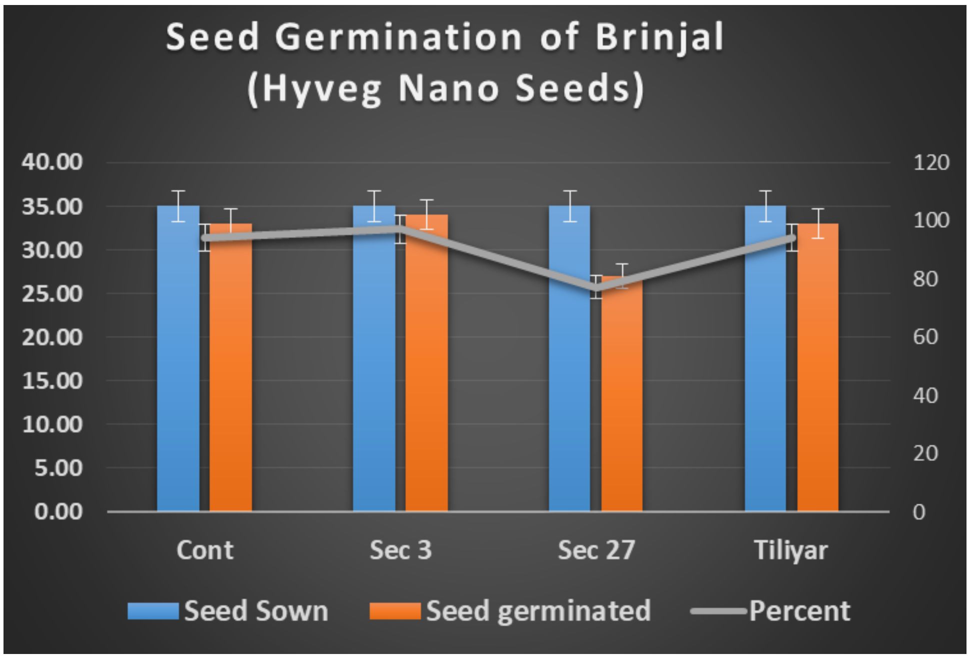
Figure 5. Effect of water samples on the brinjal seed germination.



Plant growth parameters

Brinjal cultivated in pot filled with sterile soil supplemented with organic cow dung manure and irrigated with the MC tap water as control and the groundwater extracted from the hand pump situated in Sector 3, Sector 27 and near Tilyar Lake. The growth of the plant was studied in the form of height of the plant (Shoot length / Root length) and organic content (fresh and dry weight) of the shoots and roots of the plants. In the plants irrigated with the groundwater from sector 3, one out of two plants were dead before reaching the fruit stage. The plant growth was tabulated (Table 4).

Figure 6. Seed germination of Brinjal Hyveg Nano seeds irrigated with the control tap water and ground water extracted from hand pumps from Rohtak.



	Cont	±	SD	Sec 3	±	SD	Sec 27	±	SD	Tiliyar	±	SD
Seed Sown	35.00	±	0.00	35.00	±	0.00	35.00	±	0.00	35.00	±	0.00
Seed germinated	33.00	±	1.67	34.50	±	1.73	25.80	±	1.27	33.40	±	1.67
(%)	94.28			97.14			77.14			94.28		

Fresh shoot weight of the brinjal plant when grown with the irrigation with Rohtak MC tap water was 35 ± 1.75 g, while the fresh shoot weight of the brinjal plant irrigated with the groundwater from Sector 3 was 24 g and it was 16 ± 0.80 g when irrigated with the groundwater from Sector 27; and 30 ± 1.50 g. when irrigated with the groundwater from Tilyar area (Figure 7).

One way analysis of variance (ANOVA) confirmed that the differences between the fresh shoots of the brinjal plant when irrigated with different ground waters than that of the control tap water was significant (ANOVA; p value>0.05).

Dry shoot weight of the brinjal plant when grown with the irrigation with Rohtak MC tap water was 30 ± 1.50 g, while the dry shoot weight of the brinjal plant irrigated with the groundwater from Sector 3 was 20 g and it was 10 ± 0.50 g when irrigated with the groundwater from Sector 27; and 25 ± 1.25 g. when irrigated with the groundwater from Tilyar area (Figure 7).

Similarly, the one way analysis of variance (ANOVA) results confirmed that the differences between the dry shoots of the brinjal plant when irrigated with different ground waters than that of the control tap water was significant (ANOVA; p value>0.05).

Table 1. Plant growth parameters of Bringal irrigated with MC tap water as control and the groundwater extracted from the hand pump situated in Sector 3, Sector 27 and near Tilyar Lake.

	Cont	±	SD	Sec 3	±	SD	Sec 27	±	SD	Tiliyar	±	SD
Shoot Fresh weight (g)	35.00	±	1.75	24.00	±	0.00	16.00	±	0.80	30.00	±	1.50
Shoot Dry weight (g)	30.00	±	1.50	20.00	±	0.00	10.00	±	0.50	25.00	±	1.25
Root Fresh weight (g)	30.00	±	1.50	35.00	±	0.00	10.00	±	0.50	14.00	±	0.70
Root Dry weight (g)	25.00	±	1.25	30.00	±	0.00	6.00	±	0.30	10.00	±	0.50
Shoot length (cm)	60.96	±	3.05	61.95	±	0.00	58.90	±	2.95	63.96	±	3.20
Root length (cm)	8.00	±	0.40	10.00	±	0.00	7.89	±	0.39	11.00	±	0.55

Fresh root weight of the brinjal plant when grown with the irrigation with Rohtak MC tap water was 30 ± 1.5 g, while the fresh root weight of the brinjal plant irrigated with the groundwater from Sector 3 was 35 g and it was 10 ± 0.50 g when irrigated with the groundwater from Sector 27; and 14 ± 0.70 g. when irrigated with the groundwater from Tilyar area (Figure 8).

As was observed in the case of Analysis of variance (ANOVA) (one way) of the shoot weight. The analysis of variance (ANOVA) confirmed that the differences between the fresh roots of the brinjal plant when irrigated with different ground waters than that of the control tap water was significant (ANOVA; p value>0.05).

Dry root weight of the brinjal plant when grown with the irrigation with Rohtak MC tap water was 25 ± 1.25 g, while the dry root weight of the brinjal plant irrigated with the groundwater from Sector 3 was 30 g and it was 06 ± 0.30 g when irrigated with the groundwater from Sector 27; and 10 ± 0.5 g. when irrigated with the groundwater from Tilyar area (Figure 8).

Likewise, the analysis of variance (ANOVA) confirmed that the differences between the dry root of the brinjal plant when irrigated with different ground waters than that of the control tap water was significant (ANOVA; p value > 0.05).

However, the shoot and root length was similar of the plants when irrigated with these four different waters (Figure 9). The analysis of variance (ANOVA) showed that the differences between the dry root of the brinjal plant when irrigated with different ground waters than that of the control tap water was non-significant (ANOVA; p value > 0.05).

Figure 7. Fresh and dry weight of brinjal rootsirrigated with the control tap water and ground water extracted from hand pumps from Rohtak.

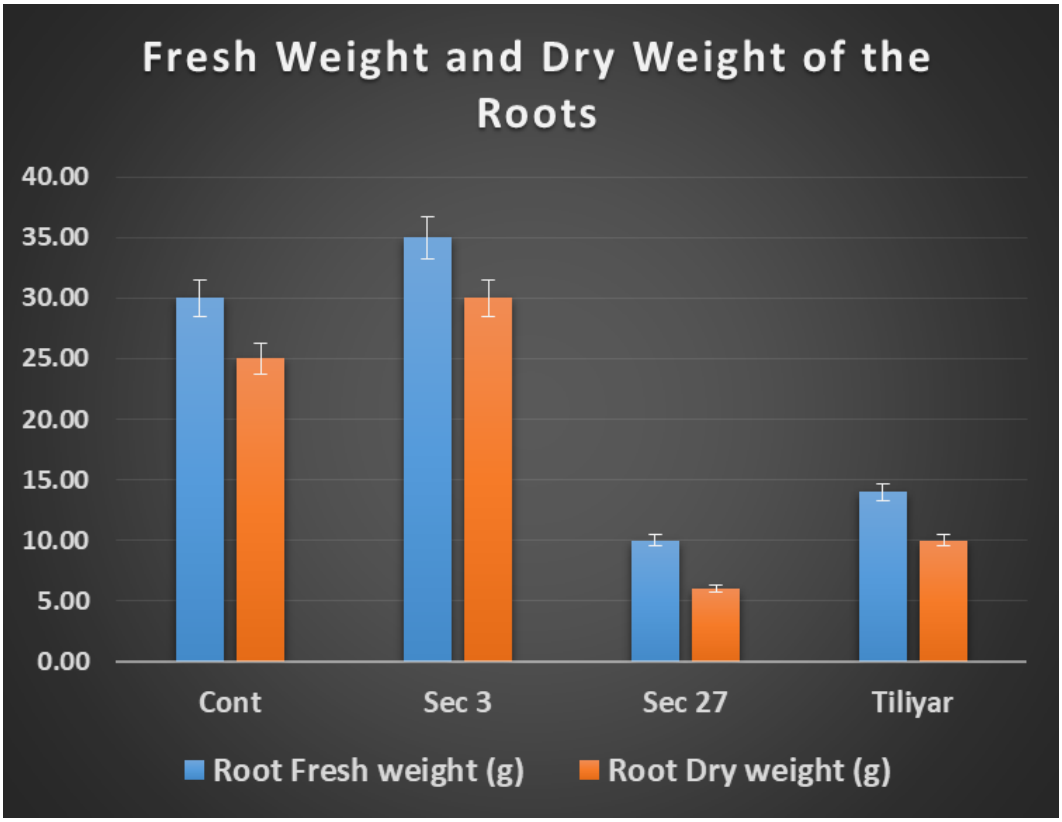


Figure 8. Fresh and dry weight of brinjal shoots irrigated with the control tap water and ground water extracted from hand pumps from Rohtak.

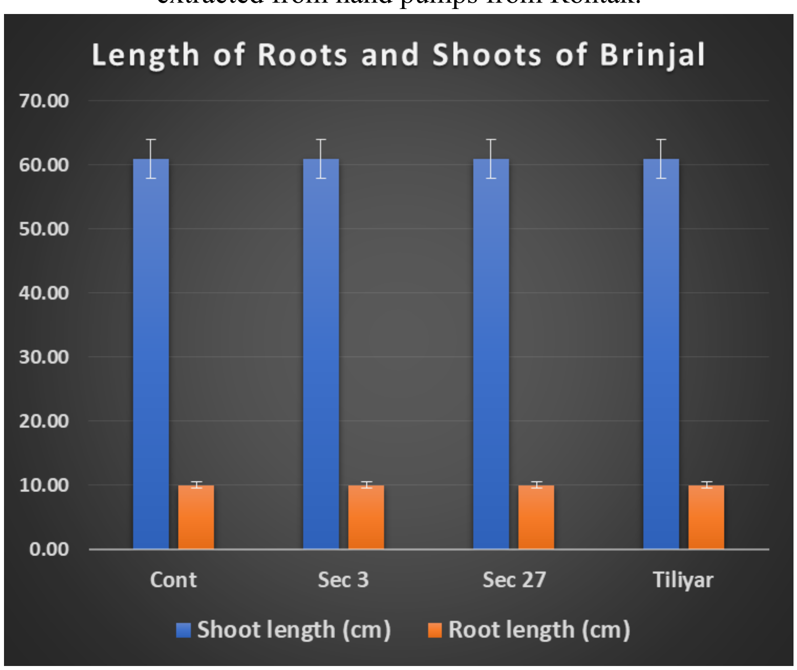
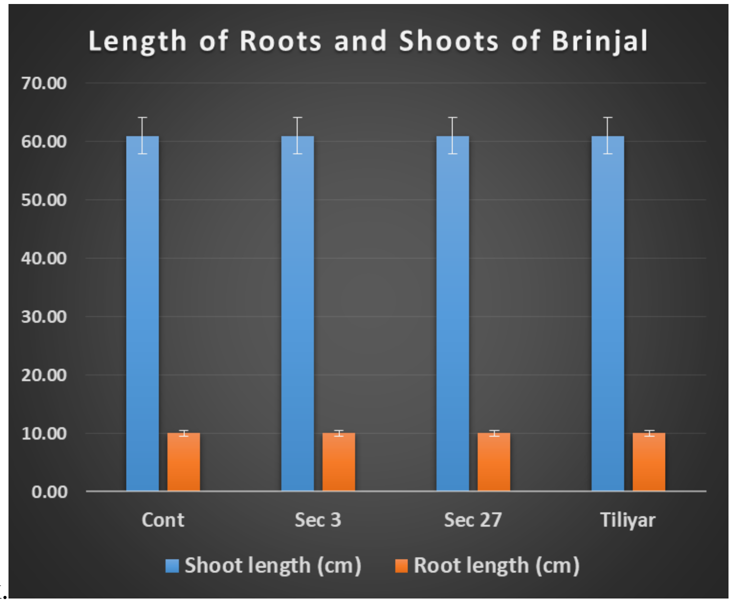


Figure 9. Root and Shoot length of brinjal irrigated with the control tap water and ground water extracted from hand pumps from Rohtak.



Brinjal Yield

Brinjal cultivated in pot filled with sterile soil supplemented with organic cow dung manure and irrigated with the MC tap water as control and the groundwater extracted from the hand pump situated in Sector 3, Sector 27 and near Tilyar Lake. The plants were routinely inspected for the plant growth. One of the plant watered from the hand pump of sector 3 was dead before the flowering stage. The plant yield was studied in the form of number of flower and fruit on the plant and size and weight of the fruits of the plants. (Table 2).

Table 1. Brinjal Plant yield influenced by the irrigation with the control tap water and ground water extracted from the hand pump situated in Sector 3, Sector 27 and near Tilyar Lake, Rohtak

	Cont	±	SD	Sec 3	±	SD	Sec 27	±	SD	Tiliyar	±	SD
Number of flower / plant	2.00	±	0.10	4.00	±	0.18	0.00	±	0.00	2.00	±	0.11
Number of fruits / plant	2.00	±	0.10	2.00	±	0.97	0.00	±	0.00	0.00	±	0.00
Fruit parameter (cm)	16.00	±	0.78	19.00	±	0.94	0.00	±	0.00	17.00	±	0.88
Wt. of fruits (g)	85.00	±	4.25	179.00	±	8.99	0.00	±	0.00	86.00	±	4.25

Mean numbers of 2 ± 0.1 fruits were developed from all the flowers in the brinjal plant when irrigated with the Rohtak MC tap water. Similarly, 2 fruits were developed from four flowers in the brinjal plant when irrigated with the groundwater from sector 3 and no flower was found in the plants that were irrigated with the groundwater from sector 27, Rohtak. The two flowers were observed in the plants that were irrigated with the groundwater from the hand pump near Tilyar Lake, Rohtak, however, these flowers did not developed into the fruits (Figure 10).

The fruit developed in the plant irrigated with the MC Rohtak tap water had mean perimeter nearly 16 ± 0.78 cm with 85 ± 4.25 g. Similarly the fruit developed in the brinjal plant when irrigated with the groundwater from sector 3 had mean perimeter nearly 19 ± 0.94 cm with 179 ± 8.99 g. Groundwater from sector 27 watering did not yield any fruit. Whereas, the fruit developed in the brinjal plant when irrigated with the groundwater from sector 27 had mean perimeter nearly 17 ± 0.88 cm with 86 ± 4.25 g (Figure 11). The statistical analysis of the yields of the brinjal cultivation with different waters resulted significant changes in the number of flowers as well the number and size of the fruits developed.

Figure 10. Number of Flower and Fruits of brinjal irrigated with the control tap water and ground water extracted from hand pumps from Rohtak.

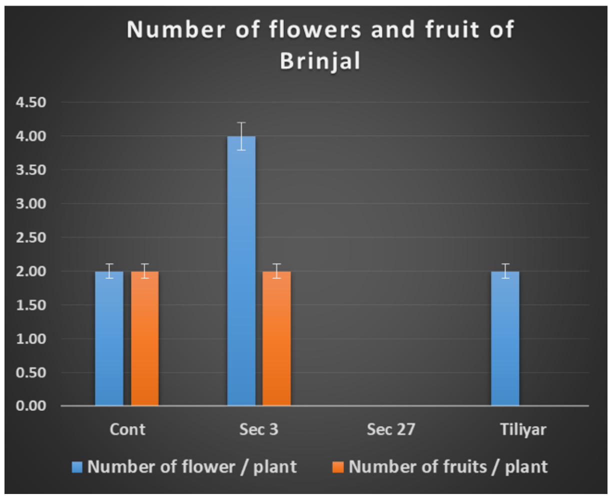
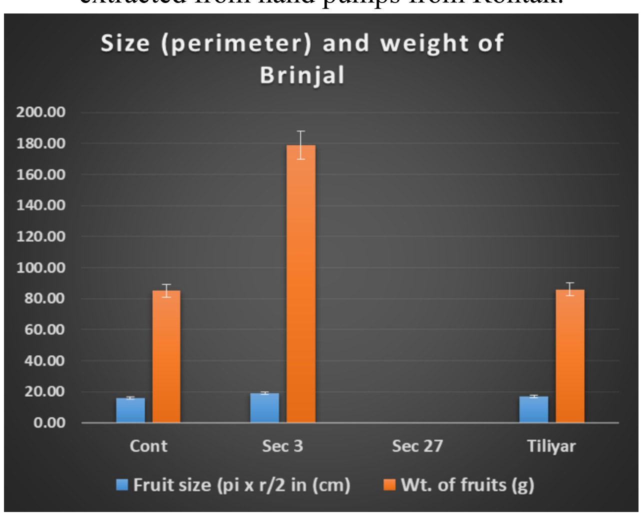


Figure 11. Number of Flower and Fruits of brinjal irrigated with the control tap water and ground water extracted from hand pumps from Rohtak.



Discussion

The present study demonstrates a clear variation in growth, biomass accumulation, and yield attributes of *Solanum melongena* (brinjal) under irrigation with groundwater from Sector 3, Sector 27, and Tilyar Lake

(Rohtak, Haryana). These variations can be attributed to differences in water quality parameters such as salinity, dissolved solids, and nutrient load, which are known to significantly influence crop physiology and productivity.

Plants irrigated with groundwater extracted from Sector 3 and Tilyar Lake water exhibited comparatively better growth performance than those irrigated with groundwater extracted from Sector 27. This is evident from higher shoot length (61.95–63.96 cm), root length (10–11 cm), and biomass accumulation (fresh and dry weights) in these treatments. In contrast, Sector 27 irrigation resulted in markedly reduced shoot fresh weight (16.00 g), root dry weight (6.00 g), and shoot length (58.90 cm), indicating growth suppression.

Such reductions are consistent with the established negative effects of elevated salinity and poor water quality on plant growth. Increased electrical conductivity (EC) and total dissolved solids (TDS) in irrigation water can impair osmotic balance, reduce water uptake, and inhibit cell expansion, leading to stunted growth (Ali, 2018). Furthermore, water stress conditions are known to decrease plant height, biomass, and root development due to reduced photosynthetic efficiency and nutrient transport (Li et al., 2024).

Interestingly, the relatively better performance under Sector 3 and Tilyar Lake irrigation suggests that moderate levels of dissolved nutrients in groundwater or lake water may enhance plant growth. Similar findings have been reported where nutrient-rich irrigation water improved plant biomass and enzymatic activity due to increased nutrient availability (Yadav et al., 2024).

A pronounced decline in reproductive parameters was observed under Sector 27 irrigation, where no flowers or fruits were recorded. In contrast, Sector 3 and Tilyar Lake treatments supported flowering (2 flowers/plant) and fruit production, with fruit weight reaching up to 179 g in Sector 3.

The absence of reproductive development under Sector 27 water indicates severe physiological stress, likely caused by excessive salinity or toxic constituents. Salinity stress is known to disrupt flowering, reduce fruit set, and ultimately diminish yield in eggplant by affecting hormonal balance and reproductive organ development (Ali, 2018).

On the other hand, improved fruit size and weight under Sector 3 irrigation suggest favorable water quality conditions that enhance nutrient uptake and assimilate partitioning. Studies have shown that appropriate irrigation water quality and nutrient availability can significantly increase fruit yield, size, and marketable quality in eggplant (Roshin et al., 2020).

Although germination percentage remained relatively high across treatments (77.14–97.14%), a slight reduction was observed under Sector 27 water. This suggests that early-stage germination is less sensitive to water quality compared to later growth stages, but prolonged exposure exacerbates stress effects. Similar trends have been reported where germination is moderately tolerant, but vegetative and reproductive stages are highly sensitive to salinity and water quality variations.

The results indicate that irrigation water quality plays a critical role in determining plant performance. Moderate levels of dissolved salts and nutrients (as likely present in Sector 3 and Tilyar Lake water) can be beneficial, whereas excessive salinity (as inferred for Sector 27) leads to osmotic stress, ion toxicity, and metabolic disruption.

This finding is particularly relevant in the context of Haryana, where groundwater quality is increasingly deteriorating due to over-extraction and anthropogenic activities. Poor-quality groundwater not only reduces crop productivity but also threatens long-term soil health and sustainability.

The data shows a significant decline in all morphological and reproductive parameters across the sites (Sec 3 < Tiliyar < Sec 27) compared to the Control. This trend is characteristic of plants grown in water contaminated with heavy metals or high organic loads.

The comparative analysis of brinjal (*Solanum melongena*) growth under different irrigation sources in Rohtak reveals significant variations in morpho-physiological parameters. The results indicate that the source of water—groundwater from Sector 3, Sector 27, or Tilyar—plays a decisive role in determining plant vigor, height, and biomass accumulation.

Conclusion

Overall, the study highlights that Sector 3 and Tilyar Lake groundwater supported better vegetative growth and yield due to relatively balanced physicochemical properties.

Sector 27 groundwater adversely affected plant growth and completely inhibited reproductive development, likely due to high salinity or pollutant load.

Similarly, following yield characteristics such as, mean number of buds/flowers per plant, mean number of fruits per plant, mean weight of fruits, and the mean perimeter of the spherical fruits were also studied. Brinjal exhibits moderate tolerance to water quality variations, but reproductive stages are highly sensitive. These findings emphasize the need for regular monitoring of groundwater quality and adoption of appropriate irrigation management strategies (e.g., blending, treatment, or alternative sources) to sustain crop productivity in semi-arid regions like Rohtak.

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