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Effect of Water Quality and Irrigation Frequency on Growth of *Melia dubia* under sole plantation in Rewari district, Haryana, India

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Abstract

Water quality and irrigation frequency play pivotal roles in the growth and development of vegetation, especially in arid and semi-arid regions. This research investigates the impact of water quality (tube well water, untreated wastewater from a local pond, and treated wastewater from the same pond) and irrigation frequency (6 times, 9 times, and subsistence irrigation per year) on the growth of Melia dubia under sole plantation in Rewari district, Haryana, India. The study, conducted from September 2021 to August 2022, employed a factorial Randomized Block Design with three replications. Results indicate that the maximum growth in plant height (225.73cm) and collar diameter (27.37mm) was observed when plants were irrigated with treated wastewater from the local pond at a frequency of nine times per year i.e. T8 (W_3I_2). In contrast, minimum growth in plant height (102.37 cm) occurred when plants were irrigated with tube well water at frequency once a year i.e. T3 (W_1I_3) and minimum growth in collar diameter (14.46mm) occurred when plants were irrigated with treated wastewater from local pond at frequency once in a year viz., T9 (W_3I_3). Statistical analysis revealed significant differences in growth parameters among treatments, emphasizing the influence of water quality and irrigation frequency. The study underscores the potential of using wastewater, when appropriately treated, as a sustainable irrigation source for forest tree plantations. The findings suggest that treated wastewater, rich in nutrients, can significantly enhance plant growth. Additionally, the research highlights the adaptability and rapid growth of Melia dubia, emphasizing its suitability for agroforestry and its diverse industrial applications, such as pulp and paper production.

Keywords: *Melia dubia*, water quality, irrigation frequency, growth parameters, wastewater treatment, sustainable agriculture, agroforestry, arid regions, Haryana.

Introduction

Water, an indispensable element for all life forms, is fundamental to the existence of living organisms. It constitutes a mere 3% of the total global water resources but remains a constant essential, upon which humanity has relied for countless millennia. With the burgeoning human population, there has been a rapid surge in the demand for water, leading to a substantial gap between the available freshwater resources and the escalating requirements. Water, in the context of agriculture, serves as the life force that sustains crop growth, ensures livestock well-being, and underpins sustainable farming practices. As the world's population continues its upward trajectory, guaranteeing a sufficient and dependable water supply becomes imperative to meet the ever-increasing demands for food production. In the realm of water resources, there exist diverse sources, including surface water, groundwater, rainwater, and recycled or reclaimed water. Additionally, agricultural drainage water, emanating from irrigated fields or lands, constitutes a viable source for irrigation purposes. When appropriately harnessed and treated, it can mitigate the necessity for additional water sources.

Effective management of agricultural drainage water not only prevents water logging but also aids in salinity control and enhances overall water utilization efficiency. Agriculture faces several pressing challenges concerning water resources, primarily stemming from climate change, water scarcity, and water quality concerns. Water quality, specifically contamination due to pollutants resulting from agricultural activities, poses a dual threat to both crop yields and human health. The unwarranted application of fertilizers, pesticides, and inadequate waste management practices contributes to the pollution of water sources, thereby engendering adverse ecological and health consequences[1]. Water quality degradation results from a myriad of activities that induce water pollution. Furthermore, the anticipated impacts of climate change will only serve to exacerbate the existing disparities between population growth and the demand for high-quality irrigation water[2]. The implementation of irrigation techniques not only curtails natural water flows but also introduces contaminants such as nutrients, major ions, and trace elements into water bodies, subsequently exerting environmental pressures.

For instance, the quality of irrigation water in the EI-Salam canal, Egypt, advocating for the treatment of drainage water before its incorporation into irrigation processes[3]. It was investigated that the drainage water utilized for irrigation in the Delhi region and detected varying concentrations of multiple heavy metals, rendering the drain water unsuitable for agricultural purposes[4]. An experiment was conducted for an evaluation of irrigation and drainage water in East South EI-Qantara, North Sinai, Egypt, revealing slightly saline irrigation water while drainage water and groundwater exhibited medium salinity levels[5]. A study on drainage water quality for potential reuse in irrigation in Borg EI-Arab, Alexandria, was conducted and concluded that vegetables irrigated with such drainage water posed health risks for both humans and animals. Therefore, a comprehensive assessment of water quality and an understanding of the factors influencing it are imperative for effective water resource management and the promotion of sustainable development[6]. Key factors influencing the chemical composition of drainage water include the drainage system, irrigation techniques, initial soil salinity, soil structure, infiltration rate, agricultural practices, and climate[7].

In the context of irrigation frequency, it is noteworthy that several studies have been conducted, revealing that the division of irrigation events into shorter intervals has a positive impact on crop growth and production[8,9]. For instance, when cultivating rose and pelargonium in rock wool and peat pots, respectively, an increased irrigation frequency has been observed to enhance transpiration rates, improve water utilization efficiency, and boost overall production[10,11]. Similarly, a favorable outcome was reported when employing shorter irrigation intervals for crops cultivated in coco fibers or perlite substrates, particularly with regard to tomato fruit yield[12,13]. In contrast, a study of gerbera cultivation in pots filled with Nisyros pumice, found that yield and quality characteristics, such as stem length and flower diameter, remained largely consistent across different irrigation frequencies. Notably, the trial with lower irrigation frequency exhibited superior water use efficiency[14].

Melia dubia Cav., commonly referred to as 'Malabar neem,' is a rapidly growing tree species belonging to the Meliaceae family[15]. It finds extensive cultivation in tropical and subtropical regions across India, Southeast Asia, and Oceania[16]. In India, *M. dubia* thrives throughout the country, except in high-altitude regions, and is frequently observed along roadsides, farm boundaries, pure plantations, and in natural forests[17]. Remarkably, it can be successfully cultivated in a wide range of soil types and elevations spanning from 600 to 1800 meters, provided there is an annual rainfall exceeding 500mm. However, the species has demonstrated its potential even in arid regions with annual rainfall as low as 200mm[18]. The temperature range within which it flourishes varies from a minimum of 0-15°C to a maximum of 30-43°C. It is typically found in areas with a relative humidity of 50-90%. *M. dubia* is a deciduous to semi-evergreen tree, reaching heights of up to 25 meters, characterized by its wide-spreading branches and lush foliage. Leaves are shed during December-January, with new foliage and flowers emerging in February-March. The fruit of *M. dubia* is a drupe, ovoid or ellipsoid in shape, exhibiting longitudinal ridges, and turns pulpy and yellowish upon ripening, emitting a sweet aroma. Fruiting primarily occurs during the cold season (October-February), with each fruit containing 3-4 seeds[19]. The suitability of *M. dubia* as an alternative raw material for the pulp and paper industries has been acknowledged, owing to its enhanced pulp recovery and superior paper strength[15]. Moreover, this versatile species possesses mechanical properties conducive to the plywood industry and offers dendro energy values essential for biomass-based power generation[20]. Beyond its industrial significance, *M. dubia* holds ecological importance, contributing to soil enrichment, afforestation, bioremediation[21], and exhibiting medicinal applications[22,23]. It has also proven to be an ideal agroforestry tree species, compatible with various understory crops[24], and without any allelopathic effects on intercrops[25]. Owing to its multifaceted uses in plywood, pulpwood, and other wood-based industries, as well as its rapid growth and adaptability to diverse agro-climatic conditions, *M. dubia* has earned the moniker "the money-spinning tree of short rotation"[19].

Materials and Methods

Experimental site: The experiment was carried out in Rewari district of Haryana state (India). The district forms the south-western part of the state and lies between 27º57'17'' to 28º27' 47''N latitude and 76º17' to 76º51' East longitude. The general elevation varies between 215 to 300 meters above mean sea level (KVK, Rewari). The region is adjacent to Rajasthan state and therefore witnesses dust storms in summer. The landscape is primarily rugged and in hilly terrain of Aravalli range. The district represents extreme arid to semi-arid climate, characterized by hot-dry and windy summers, cold winters and humid-warm monsoon months. The district receives an annual average rainfall of 545-575 mm. The rainfall primarily occurs from July to September (Monsoon season) along with a little precipitation during winter months.

Figure-1: Study area Map.

Climate and soil conditions: The minimum and maximum temperature ranges from 0^0C to 46^0C during January (winter) and May-June (summer) months respectively. The summer temperature can reach more than 46^0C during months of May to July. The lowest temperature may also reaches below 0^0C.

Due to arid climate, the soils are light coloured and moreover because of excessive evaporation, soils are calcareous and have lime nodules in the subsurface horizon. Soils have moderate salinity hazards, high salinity and moderate alkalinity hazard in the major part of the area. The texture of the soils in the district ranges from sandy to loamy sand and the pH range is 8.5-9.0.

Experimental detail: To measure the field performance of *M. dubia* on the basis of irrigation frequency and water quality, a field trial was established in the study area. Total 108 plants of *M. dubia* were planted for the experiment and the plants were procured from Forest Research Institute, Dehradun, Uttarakhand, India. The sole planting of *M. dubia* was done during September, 2021 at spacing of 4 x 2.5 m. The treatments were arranged in Factorial RBD (Randomized Block Design) with two factors, three replications and each replication consisted of four plants. The study was initiated for one year i.e. 2021-22 and recorded the growth of *M. dubia* in contrast to plant height and collar diameter on annually to evaluate the performance of trees. There are three sets of irrigation frequency and water quality whose details are given in Table-1.

Table-1: Scheduling of irrigation frequency and water quality.

Irrigation frequency	Water quality
6 times per year (I_1)	Water from tube well (W_1)
9 times per year (I_2)	Untreated wastewater from local pond (W_2)
Subsistence irrigation (I_3)	Treated wastewater from local pond (W_3)

For irrigation frequency, one set of irrigation out of the whole was reserved specifically for the winter season while the remaining irrigation was distributed equally for the non-rainy days for rest of the year in order to fulfill the water requirement. For irrigation frequency I_1, six irrigations were provided at every 40 days gap. For irrigation frequency I_2, nine irrigations were provided at every 25 days gap and for irrigation frequency I_3, only subsistence irrigation was provided. Irrigation volume allotted to each plant was 25-30 liters.

For water quality, water from tube well was used for irrigation of *M. dubia* plants in the field trial (W_1); Wastewater available in the local village pond was also used for irrigation (W_2); The pH of wastewater of the pond was < 7, so the wastewater was treated with Sodium carbonate (Na_2CO_3) to neutralize the pH (W_3) for irrigation besides addition of nematicide or disinfectant. Chloropicrin, a suitable nematicide, was applied to all three types of water to minimize the risk of damage from nematicides.

Data observation and statistical analysis: After experimental setup, growth data was recorded for plant height and collar diameter of *Melia dubia*. The observations were recorded for one year, i.e. from September 2021 to August 2022, from four plants in each plot for growth characters. The average value of data sets was calculated and used in statistical analysis using WASP 2.0 and OPSTAT statistical analysis packages.

Methodology: Water sample collection: Two water samples were collected for this study, one from a tube well and another from a local pond containing wastewater. The samples were analyzed for various parameters, including Electrical Conductivity (EC), carbonate (CO_3^-), bicarbonate (HCO_3^-), chloride (Cl^-), (Ca^{++} and Mg^{++}), and pH (Table-2).

Table-2: Physio-chemical analysis of water quality parameters.

Parameters	Tube well water	Local pond wastewater
EC	2640 µS/cm	2870 µS/cm
Carbonate (CO_3^-)	Not detectable	Not detectable
Bicarbonate (HCO_3^-)	5.0 meq/L	8.5 meq/L
Chloride (Cl^-)	20.0 meq/L	18.0 meq/L
Calcium and Magnesium (Ca^{++} and Mg^{++})	8.0 meq/L	10 meq/L
pH	8.0-8.5 (>7)	<7

For tube well water, the EC value suggests a moderate level of dissolved salts and ions, which is a generally acceptable limit for agricultural use. The absence of carbonate in water indicates the absence of significant alkaline characters. The concentration of bicarbonate suggests slightly alkaline water. Chloride was at moderate level and the combined concentration of calcium and magnesium indicates the presence of hardness.

For local pond wastewater, the EC value suggests a higher concentration of dissolved salts and ions, indicating the potential presence of pollutants or runoffs. Minimal amount of carbonate indicates low alkalinity from this ion. Bicarbonate level indicates greater alkalinity. The combined concentration of calcium and magnesium indicated higher water hardness as compared to tube well water.

Data collection for estimating plant height and collar diameter: Data collection for estimating plant height and collar diameter was conducted by using standardized procedures and tools. Plant height measurements were taken by using a measuring tape, with the tape positioned vertically from the base of the plant to the tip of the highest leaf or terminal bud. Collar diameter measurements were obtained by using a digital vernier caliper, which was carefully positioned around the base of the plant stem at the soil line to determine the diameter of the stem collar. Measurements were recorded in millimeters (mm) for collar diameter and centimeters (cm) for plant height to ensure precision and consistency across data points. Data collection was performed during the time of plantation in Sept. 21 and repeated after one year in Aug. 22 to assess the growth and developmental changes in *M. dubia* over the study period.

Results and Discussion

Effect of irrigation frequency and water quality on plant height: The analysis indicates that the highest plant height was achieved when plants were irrigated with treated wastewater from a local pond at a frequency of nine times per year (Figure-2). This outcome is represented by treatment T8 (W_3I_2), with a recorded plant height of 225.733cm. The next best result was observed in treatment T2 (W_1I_2), where plants were irrigated with tube well water at a frequency of nine times per year, resulting in a plant height of 214.78cm. In contrast, the lowest plant height was found in treatment T3 (W_1I_3), where plants were irrigated with tube well water only once per year, with a recorded height of 102.373cm (Table-3).

Regarding the effect of water quality, statistical analysis showed that treatments T1, T5 and T6 did not exhibit significant differences in plant height, suggesting that these treatments had a similar impact on plant growth despite variations in irrigation frequency. Conversely, treatments T3, T7 and T8 demonstrated statistically significant differences, indicating that water quality had a noticeable effect on plant height in these cases. The significance of the treatments was determined at both 1% and 5% levels of significance using critical difference (CD) values. The ANOVA table with CD values at 1% and 5% is shown in Table-5 and the comparison of treatment means with CD values is shown in Table-4. Overall, the results suggest that both irrigation frequency and water quality significantly influenced plant height, with higher frequencies and the use of treated wastewater generally yielding taller plants.

Table-3: Comparison of average plant height during and after one year of planting.

Treatments	Mean height (cm) Sole crop		Height increment after one year (cm)
	Planting time (2021)	First year (2022)	
T1 (W_1I_1)	59.84	152.56	92.72
T2 (W_1I_2)	56.61	214.78	158.17
T3 (W_1I_3)	56.25	102.37	46.12
T4 (W_2I_1)	61.18	175.00	113.82
T5 (W_2I_2)	60.90	147.75	86.85
T6 (W_2I_3)	53.79	159.08	105.29
T7 (W_3I_1)	58.88	166.79	107.91
T8 (W_3I_2)	62.24	225.73	163.49
T9 (W_3I_3)	53.82	117.37	63.55

Table-4: Comparison of Treatment Means with Critical Difference (0.05) (Plant height).

Treatment no.	T8	T2	T4	T7	T6	T1	T5	T9	T3
Treatment average	225.73	214.78	175.00	166.79	159.08	152.56	147.75	117.37	102.37
Critical difference (CD) compared	a	ab	bc	c	cd	cd	cd	de	e

Table-5: ANOVA table.

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob
Within replications	2	325.848	162.924	0.251	0.781
Within treatments	8	38658.8	4832.35	7.453	0
Error	16	10373.857	648.366	-	-
Total	26	-	-	-	-

Coefficient of Variation =15.681. Treatments found significant at 1% & 5% level of significance. CD (0.01)=60.729, CD (0.05)= 44.076

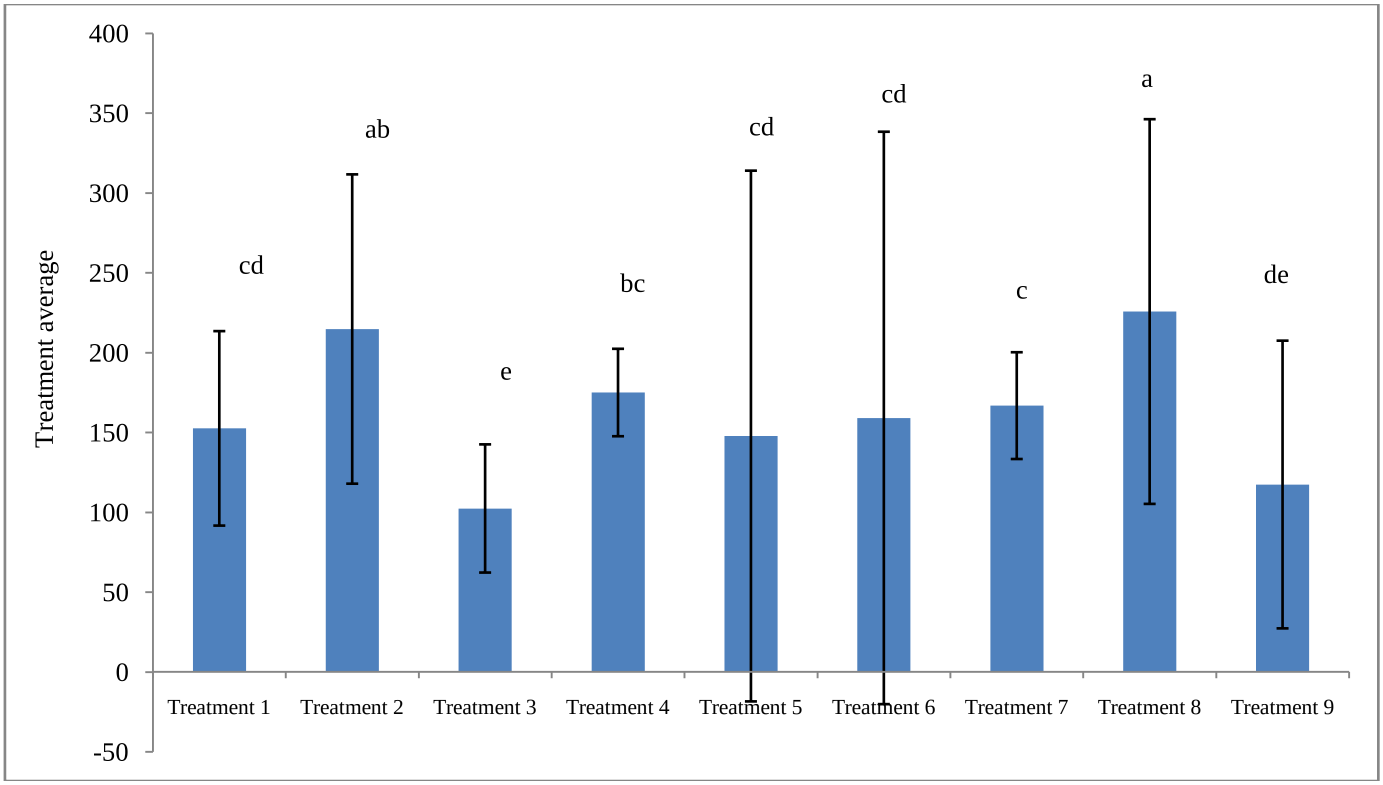

Figure-2: Comparison of treatment means with critical difference on plant height of *M. dubia.*

Effect of irrigation frequency and water quality on collar diameter: The study revealed that the greatest collar diameter was achieved in plants irrigated with treated wastewater from a local pond at a frequency of nine times per year (Figure-3). This result was observed in treatment T8 (W_3I_2), with a collar diameter of 27.37 mm. The second-highest collar diameter was noted in treatment T2 (W_1I_2), where plants were irrigated with tubewell water at the same frequency, reaching 27.46 mm. On the other hand, the smallest collar diameter was obtained from treatment T9 (W_3I_3), in which plants were irrigated with treated wastewater from a local pond at a reduced frequency of only once per year. This treatment recorded a collar diameter of just 14.46 mm (Table-6).

Regarding the effect of water quality, statistical analysis indicated that treatments T1, T5, and T6 were statistically similar in terms of collar diameter, suggesting that these treatments had a comparable impact on plant growth despite variations in irrigation frequency. However, treatment T8 demonstrated a significant result in terms of collar diameter, indicating a distinct effect due to the high frequency of irrigation with treated wastewater (table). These findings suggest that both irrigation frequency and water quality significantly affect collar diameter, with higher irrigation frequencies generally leading to increased collar diameters. Treatments using treated wastewater with high irrigation frequency resulted in greater collar diameters, while reduced frequencies led to significantly smaller diameters.

The significance of the treatments was determined at both 1% and 5% levels of significance using critical difference (CD) values. The ANOVA table with CD values at 1% and 5% is shown in Table-8 and the comparison of treatment means with CD values for collar diameters shown in Table-7. Overall, the results suggest that both irrigation frequency and water quality significantly influenced plant collar diameter.

Height and Collar diameter increment of *M. dubia* after one year: The results indicated that the greatest increase in plant height after one year occurred in treatment T8 (W_3I_2), which involved irrigation with treated wastewater from a local pond nine times per year. Conversely, the smallest increase in height was observed in treatment T3 (W_1I_3), where plants were irrigated with tubewell water only once a year.

Similarly, the increase in collar diameter after one year followed the same trend, with the maximum increment seen in T8 (W_3I_2) and the minimum increment in T3 (W_1I_3). Interestingly, when comparing the collar diameter increments with the collar diameter measured in August 2022, there was a shift in which treatment showed the lowest measurement. While T3 (W_1I_3) had the lowest collar diameter increment after one year, the smallest collar diameter in August 2022 was observed in treatment T9 (W_3I_3), which used treated wastewater from a local pond with a single irrigation per year.

This variation in results regarding the minimum collar diameter can be attributed to the survival rate of the plants.

In treatment T3 (W_1I_3), 12 plants were planted, but only 9 survived, with one plant lost from each of the three replications. This lower survival rate in treatment T3 (W_1I_3) caused variations in the collar diameter measurements, which explains why the minimum collar diameter increment differed from the baseline collar diameter observed in August 2022 (Figure-4).

These findings highlight the importance of considering plant survival rates when analyzing treatment outcomes in terms of plant growth. Reduced survival rates can significantly influence growth metrics, leading to discrepancies in the results. This underscores the need for proper plant management and care to ensure accurate and reliable data in experimental studies.

Table-6: Comparison of average collar diameter during and after one year of planting.

Treatments	Mean Collar diameter (mm) Sole crop		Collar diameter increment after one year (mm)
	Planting time (2021)	First year (2022)	
T1 (W_1I_1)	6.40	20.71	14.31
T2 (W_1I_2)	6.75	27.46	20.71
T3 (W_1I_3)	6.76	14.51	7.75
T4 (W_2I_1)	7.85	24.25	16.40
T5 (W_2I_2)	7.19	17.98	10.79
T6 (W_2I_3)	7.17	18.64	11.47
T7 (W_3I_1)	6.75	21.68	14.93
T8 (W_3I_2)	7.42	28.37	20.95
T9 (W_3I_3)	6.57	14.46	7.89

Table-7: Comparison of Treatment Means with Critical Difference (0.05) (Collar diameter).

Treatment no.	T8	T2	T4	T7	T1	T6	T5	T3	T9
Treatment average	28.37	27.46	24.25	21.68	20.71	18.64	17.98	14.51	14.46
Critical difference (CD) compared	a	ab	abc	bc	cd	cd	cd	d	d

Table-8: ANOVA table.

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob
Within replications	2	36.728	18.364	1.376	0.281
Within treatments	8	619.697	77.462	5.804	0.001
Error	16	213.524	13.345	-	-
Total	26	-	-	-	-

Coefficient of Variation = 17.481, Treatments found Significant at 1% and 5% level of significance CD (0.01) = 8.713 CD (0.05) = 6.323.

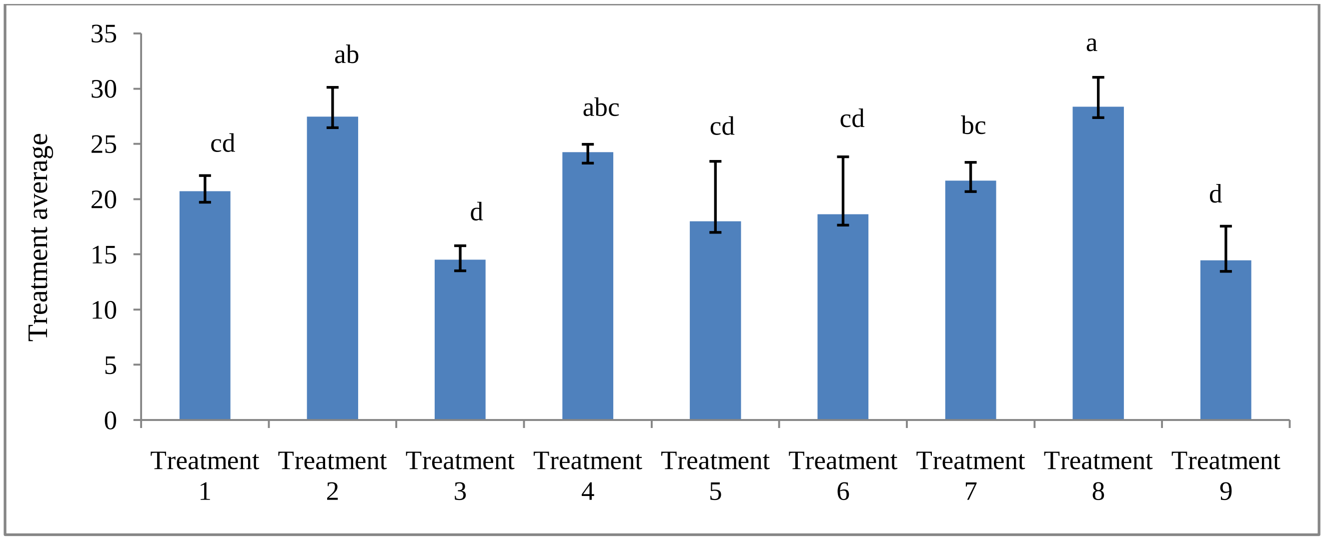

Figure-3: Comparison of treatment means with critical difference of collar diameter of *M. dubia*.

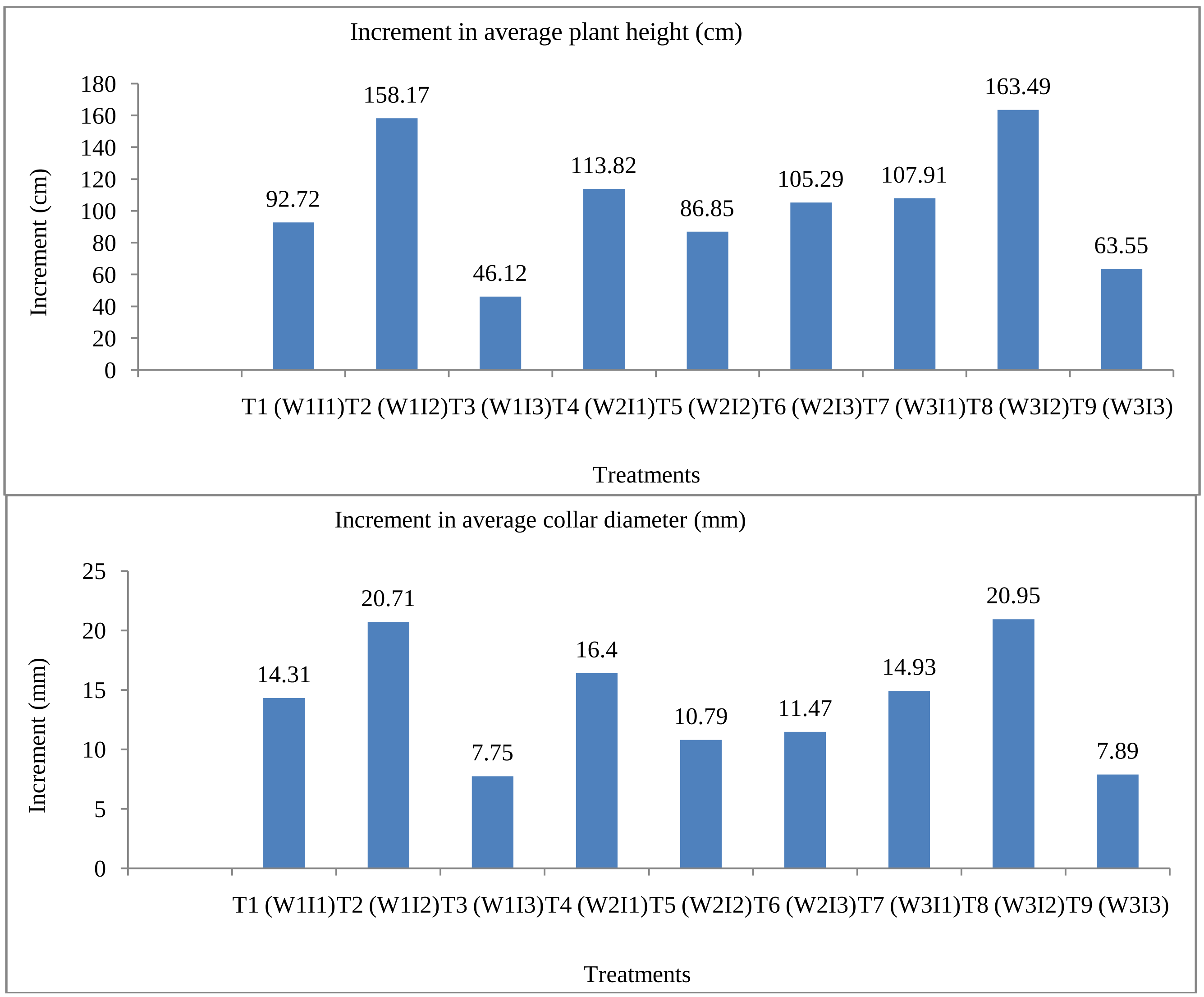

Figure-4: Height and collar diameter increment of *M. dubia* after one year.

Discussion: The study investigated the effects of irrigation frequency and water quality on the growth of *Melia dubia* in the Rewari district of Haryana, India. The key findings suggest that irrigation frequency and water quality significantly impact plant height and collar diameter, with specific treatment combinations showing enhanced growth compared to others. This discussion focuses on the implications of these findings, the factors contributing to the observed outcomes, and potential recommendations for future agricultural practices.

Impact of Irrigation Frequency and Water Quality on Plant Height: The results indicate a strong correlation between irrigation frequency, water quality, and plant height. Treatment T8 (W_3I_2), which involved irrigation with treated wastewater from a local pond nine times per year, achieved the greatest plant height, suggesting that increased irrigation frequency and use of treated wastewater can lead to enhanced growth. This aligns with previous research demonstrating that frequent irrigation with appropriate water quality can improve plant growth and development[8,9].

The statistically significant differences in plant height among treatments underscore the importance of water management practices in agriculture. High-frequency irrigation, coupled with treated wastewater, may provide adequate moisture levels and essential nutrients to plants, promoting robust growth. This is supported by the increased plant height observed in treatments with higher irrigation frequencies, such as T2 (W_1I_2) and T8 (W_3I_2). Conversely, treatments with lower irrigation frequencies, such as T3 (W_1I_3), exhibited reduced plant height, indicating that insufficient water supply can limit growth.

Influence of Irrigation Frequency and Water Quality on Collar Diameter: Similar trends were observed in collar diameter, with treatment T8 (W_3I_2) is achieving the highest collar diameter and treatment T3 (W_1I_3) showing the lowest. The greater collar diameter in high-frequency irrigation treatments aligns with studies suggesting that increased water supply enhances stem thickness and overall plant robustness[13]. The statistically significant differences in collar diameter among treatments emphasize the critical role of water quality and frequency in determining plant structure and strength.

Interestingly, the shift in the lowest collar diameter from T3 (W_1I_3) to T9 (W_3I_3) after one year could be attributed to variations in plant survival rates. Lower survival rates in T3 (W_1I_3) resulted in discrepancies in collar diameter measurements, highlighting the importance of plant survival for accurate growth assessments. This observation underscores the need for consistent monitoring and proper plant management to ensure reliable results in experimental studies.

Implications for Sustainable Agricultural Practices: The study's findings have significant implications for sustainable agricultural practices. The use of treated wastewater from local ponds as an irrigation source demonstrates the potential for reusing non-traditional water sources in agriculture. This approach not only reduces the reliance on freshwater resources but also contributes to sustainable water management by recycling wastewater for irrigation purposes. However, caution must be exercised, as the use of untreated wastewater can pose risks to plant health and soil quality, as evidenced by the lower plant height and collar diameter in some treatments.

Higher irrigation frequency generally yielded better growth outcomes, suggesting that consistent water supply is crucial for optimal plant development. However, these results must be balanced with water conservation efforts and sustainable practices to avoid over-extraction and environmental degradation. Implementing efficient irrigation techniques, such as drip or subsurface irrigation, may help optimize water use while ensuring consistent plant growth[26].

Conclusion

108 plants of *M. dubia* were planted to assess the growth parameters viz., Height and Collar diameter in dry conditions of Rewari district of Haryana state on the basis of Water quality parameters and Irrigation frequencies. The results showed that the plants performed significantly well in T8 (W_3I_2) i.e. plants which were irrigated nine times per year with treated wastewater from local pond and showed the maximum increment in height and collar diameter as well. So, based on this study, it was concluded that the availability of wastewater in nearby agricultural fields can be used for irrigation in forest tree plantations by treating them with suitable nematicides i.e. Chloropicrin and by neutralizing their pH by applying Sodium carbonate (Na_2CO_3) in the wastewater. Using this wastewater to irrigate crops or farmland is a sustainable and low-cost method to conserve water and reduce wastage. It also helps to get higher crop production and farmers can increase their yields by irrigation. This is because they have access to water and are able to plant more crops. There are other benefits of using the wastewater for irrigation which includes high nutrient content, high and good quality crops and it is also an eco-friendly in nature. Israel is the best example of using the wastewater. Israel has always faced water shortages. Water supply in the country is dependent on water sources other than natural, such as desalination and reclaimed water. Therefore, Israel is well-known for its desalination capabilities. Israel has boosted economic growth and resilience to extreme droughts by wastewater reclamation. Most impressive of all is the way that Israel has revolutionized water recycling. It is the leader in water reclamation, having managed to recycle and treat about 90% of its wastewater. Most of its wastewater effluent is used for irrigating agricultural crops. About 10% of this is used for the country’s efforts in fighting fires and restoring river flows[27].

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