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Germination and growth performance of wood apple (*Limonia acidissima* L.) in the semi-arid region of Southern Rajasthan

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Abstract
Limonia acidissima L. (wood apple) is a nutrient-rich yet underutilized fruit tree with growing commercial demand. However, its propagation is mainly seed-based, which faces challenges due to low viability, especially from fresh fruits. This study investigated seed germination and growth under different soil treatments, focusing on salinity stress and the use of vermicompost as an eco-friendly amendment.
Eight treatments were applied: one control, one with vermicompost, and six with increasing NaCl concentrations (50g to 300g). The best results were observed in T2 (soil + vermicompost), indicating enhanced germination and seedling vigor. T3 (soil + 50g NaCl) showed poor germination (0.33), while T4 to T8 (100g-300g NaCl) had zero germination.
The findings confirm that higher salinity inhibits germination, whereas organic amendments like vermicompost significantly improve growth. This approach offers a sustainable solution to increase the cultivation of *L. acidissima* and meet its market demand.

Keywords: Wood apple, germination, bel, salinity, semi-arid, vermicompost

Introduction
Wood apple (*Limonia acidissima* L.) is an important tree due to its rich, underutilized fruit. Native to India and neighboring countries like Sri Lanka, Pakistan, and Bangladesh, wood apple is commonly found in field-edge and roadside plantations, though well-maintained orchards are rare (Sau. *et al.*, 2019) [7]. In India, it grows in the plains of North, south, east and central regions, including Maharashtra, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Madhya Pradesh, and the western Himalaya. The pulp of *Limonia acidissima* is rich in essential medicinal compounds, proteins, and carbohydrates. Moreover, India is the leading country in terms of the use of traditional plants. India is known for its vast variety of medicinal plant species of about 17000 species, of which around 8000 are classified as herbal plants (Vijayvargia and Vijayvergia, 2014) [13].
As seed propagation is considered convenient and successful method, many researchers have focussed on various seed treatments, pre- and post-germination treatment. Experiments on seed priming methods to enhance germination and growth have been conducted and according to Sau *et al*., (2019) [7] from among the eight treatments they studied i.e., GA_3 50 ppm and 100 ppm, KNO_3 50 ppm and 100 ppm, Thiourea 50 ppm and 100 ppm, control, and water soaking, GA_3 100 ppm resulted in the highest germination.
This study will explore the germination and growth performances of *Limonia acidissima* under different conditions, such as Soil type, organic manure (vermicompost), and salt concentration. Saline soil is becoming a significant issue, threatening agricultural land. High salinity affects 10% of soils and 50% of irrigated land globally (Guo *et al*., 2015) [12]. Salt tolerant species can reduce the germination rates of crops, while halophyte plants can withstand saline conditions and grow.
The experiment will examine *Limonia acidissima* under different soil conditions, including the use of vermicompost and varying salt concentrations, to assess their effects on germination and growth.

Vermicompost

Vermicompost is an exceptional organic manure known for its moisture-retaining properties, high-water porosity capacity, aeration, and drainage. It is widely used as a soil amendment to improve crop production and protect plants from pathogens (Singh *et al*., 2008; Dominguez, 2004) [28, 20]. Vermicompost is produced by using earthworms to create enriched compost for the plants. Numerous studies have confirmed that vermicompost has significant positive effects on plant growth. It is rich in phosphorus-solubilizing bacteria, which help to solubilize phosphorus from the insoluble form in organic waste material, making vermicompost as a potential phosphatic biofertilizer.

Vermicompost is also abundant in exchangeable nutrients such as NO_3 -, PO_{42}-, Mg_2+, Ca_2+, SO_{42}-, and other micronutrients, making it a powerful nutritive substrate for crops (Singh *et al*., 2008) [28]. Additionally, it contains humic acids (HAs), which regulate various metabolic processes and plant development.

Saline soil

Saline soil is an increasing concern, causing harm to the arable land. High saline affects 10% of soils and 50% of irrigated land globally (Guo *et al*., 2015) [12]. Salt-tolerant species can significantly reduce germination rates of crops, while halophyte plants are capable of withstanding and thriving in saline conditions. The most critical stages in the life cycle of salt-tolerant plants or halophytes are the germination and establishment phases. Salinity is the major challenge that threatens crops productivity in arid and semi-arid regions (Mohammed *et al*., 2008) [30]. The primary causes of high saline content include limited water availability, poor drainage, poor quality of irrigated water. (Shibli, 1993) [35].

Materials and Methods

The experiment was conducted at the Mewar University Campus in the Chittorgarh district of Rajasthan. The study was carried out over a period of 5 months, from February 2022 to June 2022. During this period, the average temperature was approximately 20.1 degrees Celsius, with rainfall of 3mm and relative humidity of 37%. Geographically, Rajasthan is located between 23.3 degree Celsius to 30.12 degree Celsius North latitude and 69.30 to 78.17 degree Celcius East longitude, with the Tropic of Cancer passing through its southernmost tip.

Sampling is a statistical process where a predetermined number of observations are taken from a large population**.** The selected items constitute a sample. According to Kothari (2019), the sample should be representative of population characteristics without bias, to ensure valid and reliable conclusions.

Uninfected and matured fruits of fully grown mother trees, located around the Chittorgarh district, were used for the present experiment. These mature fruits were collected in February and brought to the laboratory, where they were allowed to ripen. Once ripe, indicated by the fruit giving off a pleasant sour smell, the fruits were open, de-pulped by scooping and soaked in the water for about half an hour After thorough washing with the running water, the seeds were separated using a sieve and placed in partial sunlight to dry for further experimentation.

Experimental polybags (8" size) were filled with sieved soil, and pH (Potential Hydrogen) and EC (Electrical Conductivity) were estimated before starting the study. The pH and EC of both the soil and irrigation water were measured using a pH meter and a conductivity meter.

Methods of salinity creation

The soil was collected from the University farm and passed through a 2 mm sieve for the control treatment. For the treatment involving vermicompost, the soil was mixed with vermicompost in a 1:1 ratio and thoroughly blended. This mixture was then filled into all the polybags and set into three replicates. A total of twenty-five seeds were sown in each polybag, which were arranged in the open air and exposed to normal sunlight for the control treatment (T_1).

For the other treatments (T_2, T_3, T_4, T_5, T_6, T_7), the same number of polybags were filled with untreated soil that had specific electrical conductivity (EC) and pH levels. The soil and vermicompost mixture (1:1 ratio) used for treatments had an EC of 0.01891dS/m and pH of 7.8.

Treatment details

Sl. No	Treatments	Salinity
1	T_1 Control	No NaCl
2	T_2 Vermicompost + Soil	No NaCl
3	T_3 Soil + Salt	50g of NaCl
4	T_4 Soil + Salt	100g of NaCl
5	T_5 Soil + Salt	150g of NaCl
6	T_6 Soil + Salt	200g of NaCl
7	T_7 Soil + Salt	250g of NaCl
8	T_8 Soil + Salt	300g of NaCl

Growth studies

Treatment

Seeds were sown in varying concentrations of NaCl (50, 100, 150, 200, 250, 300 g) along with two control treatments: one with NaCl and one with vermicompost. Ten random seedlings from each experimental group were observed and recorded three times at one-month intervals during the experimental period.

Fresh and dry matter estimation

Fresh weight was measured using the following procedure: at different intervals, both treated and untreated seedlings were washed under tap water, then rinsed in distilled water.

Growth treatment

The study followed Randomized Block Design (RBD) and was conducted in the Mewar University Nursery. The nursery roof was covered with a green shed net. A total of eight treatments of soil samples and irrigation water (pH 7.4, 1891dS/m and TDS 936 ppm) were used. During the experiment, an equal amount of tap water was provided to each polybag daily.

Germination was observed 29 days after sowing, and subsequent observations were made at regular intervals to monitor the progress. Growth characteristics, such as seedling height, number of leaves, and shoot diameter, were measured at one-month intervals.

Plant germination was recorded daily for two months. Growth parameters such as plant height (cm), girth (cm), leaf count, and stem diameter were measured at each one-month interval. The height was measured with a ruler, while the stem diameter was measured using a vernier caliper.

Table 1: Average germination recorded

S. No.	Treatments	Germination
1	T_1 Control	7.67
2	T_2 Vermicompost + Soil	10.33
3	T_3	0.33
4	T_4	0
5	T_5	0
6	T_6	0
7	T_7	0
8	T_8	0
9	SE.d=	2.34
10	CD (5%) =	5.01
11	CV=	88.06
12	TAB F (5%) Treatment	S
	Replication	
13	TAB F (1%) Treatment	S
	Replication	NS

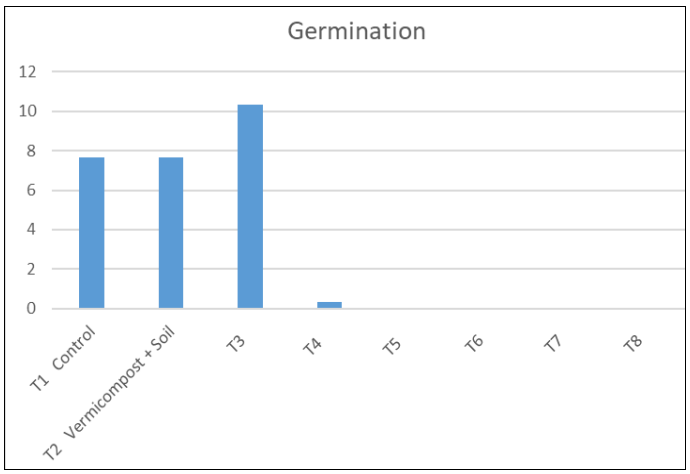

Chart 1: Germination recorded

Growth Characteristics

Seedling length: Seedling length was measured using a measuring tape and recorded three times, at 30, 60, and 90 days.

Table 2: Average seedling lengths

S. No.	Treatments	Seedling Length (Centimetre)		
		30 days	60 days	90 days
1	T_1 Control	6.80	7.43	14.75
2	T_2 Vermicompost + Soil	3.81	11.54	15.94
3	T_3	1.67	2.67	4.30
4	T_4	0	0	0
5	T_5	0	0	0
6	T_6	0	0	0
7	T_7	0	0	0
8	T_8	0	0	0
9	SE.d=	1.73	1.62	2.24
10	CD (5%) =	3.71	3.48	4.80
11	CV=	137.93	73.54	62.64
	TAB F (5%) Treatment	S	S	S
	Replication			
13	TAB F (1%) Treatment	NS	S	S
	Replication	NS	NS	NS

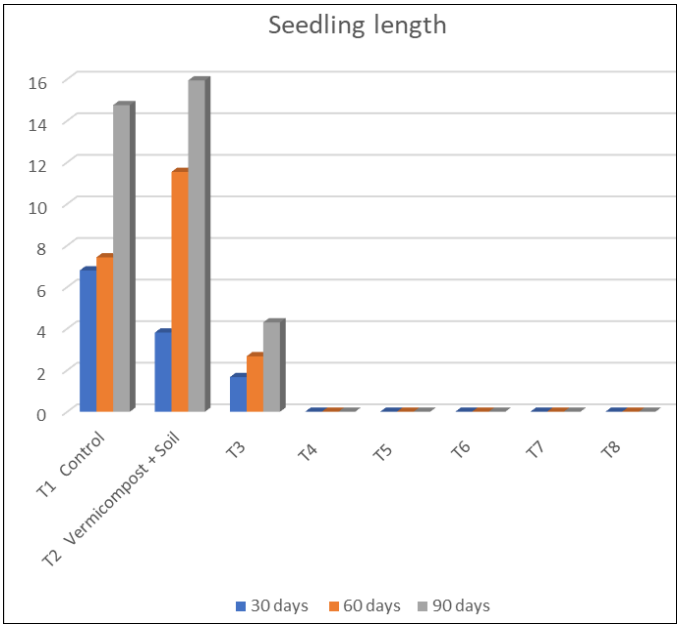

Chart 2: Seedling Length

Number of leaves/ plants: The number of leaves from all the plants was counted and recorded to find the average number of leaves/plant at 30, 60,90 days

Table 3: The average number of leaves

S. No.	Treatments	Number of leaves		
		30 days	60 days	90 days
1	T_1 Control	8.73	10.65	14.54
2	T_2 Vermicompost + Soil	8.86	11.85	16.14
3	T_3	2	2	3.67
4	T_4	0	0	0
5	T_5	0	0	0
6	T_6	0	0	0
7	T_7	0	0	0
8	T_8	0	0	0
9	SE.d=	1.16	1.47	2.06
10	CD (5%) =	2.48	3.16	4.41
11	CV=	57.90	60.92	58.66
12	TAB F (5%) Treatment	S	S	S
	Replication			
13	TAB F (1%) Treatment	S	S	S
	Replication	NS	NS	NS

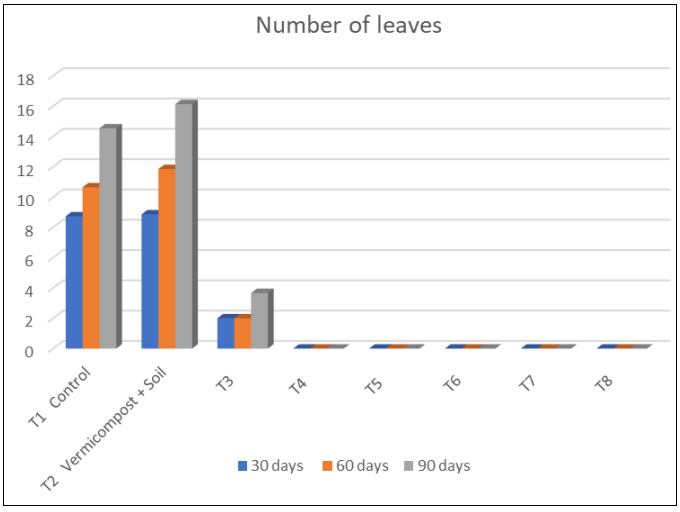

Chart 3: Number of Leaves

Shoot Diameter: The seedling shoot diameter is measured using a calliper and the data in three intervals, i.e., 30, 60, and 90 days.

Table 4: Average shoot diameter

S. No.	Treatments	Shoot diameter		
		30 days	60 days	90 days
1	T_1 Control	6.80	7.43	14.75
2	T_2 Vermicompost + Soil	3.81	11.54	15.94
3	T_3	1.67	2.67	4.30
4	T_4	0	0	0
5	T_5	0	0	0
6	T_6	0	0	0
7	T_7	0	0	0
8	T_8	0	0	0
9	SE.d=	1.73	1.62	2.24
10	CD (5%) =	3.71	3.48	4.80
11	CV=	137.93	73.54	62.64
12	TAB F (5%) Treatment	S	S	S
	Replication			
13	TAB F (1%) Treatment	NS	S	S
	Replication	NS	NS	NS

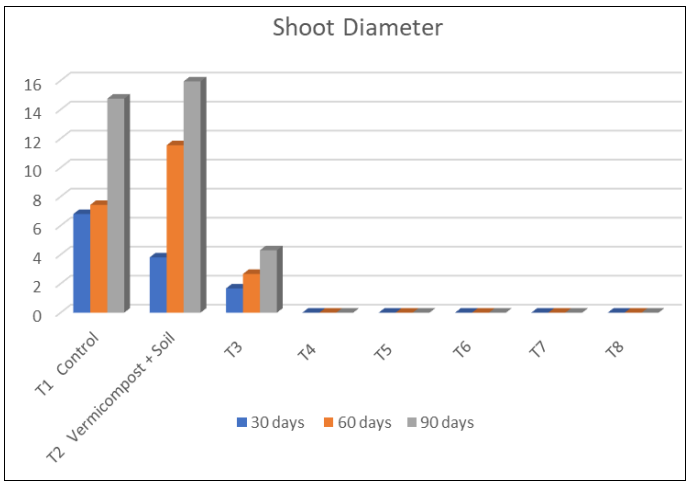

Chart 4: Shoot Diameter

Summary and Conclusion

The present experiment, titled" Germination and Growth Performance of *Limonia acidissima* L. (Wood Apple) in semi-arid region of South-Western Rajasthan," was conducted at the Forest Nursery, Department of Forestry, Mewar University, Chittorgarh, Rajasthan.

The results of this study on germination and growth parameters, with different treatments of *Limonia acidissima*, have been discussed and compared with previous research conducted both in India and internationally. The experiment followed a Randomized Block Design (RBD) with 8 treatments, three replications, and a total duration of 6 months for the entire experimental work and data collection.

Among all eight treatments, the best results were observed in T_2 (Vermicompost+ soil), which showed the highest germination rates. In contrast, poor or zero germination was noted in treatments with higher salinity levels. Specifically, T_3 (Soil+50 gm NaCl) resulted in poor germination (0.33%). T_4 (soil+100gm NaCl), T_5 (soil+150gm NaCl), T_6 (soil+200gm NaCl), T_7 (soil+250gm NaCl), and T8 (soil+300gm NaCl) recorded zero germination. These results suggest that increased salt concentration negatively impacts the germination of wood apple seeds, with higher salinity levels leading to complete inhibition of germination.

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