

Original Research Article

Impact of Organic Seed Priming Formulations on Germination and Seedling Growth of Acid Lime (*Citrus aurantifolia* Swingle) cv. Kagzi - Unleashing the Potential

Abstract

The primary objective of this research study was to examine the impact of organic seed priming formulations applied on the germination and seedling growth of acid lime cv. Kagzi at CCS Haryana Agricultural University, Hisar, during the period 2020-2021. The study comprised six distinct treatments of organic formulations, including beejamrit, cow urine (50% and 100%), cow dung, cow dung slurry, and a control (without soaking). The seeds were soaked for a duration of 24 hours. The experiment was conducted using a completely randomized design with three replications.

The study findings revealed interesting outcomes. The control (without soaking) exhibited the highest germination percentage (45.17) and germination rate (2.38), followed closely by the beejamrit. Furthermore, the beejamrit treatment demonstrated remarkable seedling growth at 180 days after sowing, with the highest values recorded for seedling diameter (3.23 mm), seedling shoot length (36.90 cm), fresh shoot weight (3.26 g), fresh root weight (1.26 g), tap root length (37.57 cm), and survival percentage (91.50). Cow dung slurry also exhibited notable performance in terms of seedling growth parameters at 180 days after sowing.

Additionally, cow dung slurry showcased the highest number of secondary roots (50.00), number of leaves per seedling (31.67), leaf chlorophyll content (33.80 SPAD), and nitrogen content (1.52%), closely followed by the beejamrit treatment. The cow dung slurry treatment yielded the highest values for sturdiness quotient (SQ) (11.52), seedling quality index (SQI) (0.178), and shoot-to-root ratio (2.97), with beejamrit treatment ranking second in these metrics.

KEYWORDS: Beejamrit, Cowdung slurry, Cowdung, Cowurine, Kagzi lime, Organic formulations, Seed priming

Introduction

Citrus is considered world's most common, popular, and favorite fruit. In tropical and sub-tropical regions, citrus fruit is widely grown and enjoys a prominent place among the people. It possesses greater adaptability to different climatic conditions. Internationally citrus plantation is confined to 0-40° latitude covering different regions having different soil and climatic condition (**Ghosh, 2000**). Globally citrus is grown in 114 countries. The world citrus is dominated by sweet orange (71%) followed by mandarin (13%), lime & lemon (10%), grapefruit and other species (6%) (FAO, 2020-21). India is the sixth-largest producer of citrus in the world. In India, citrus is grown in an area of about 1104.90 thousand hectares with a production of 14535.90 thousand metric tons with productivity of 13.2 metric tons per hectare (**Indiastat, 2022-23**) and the third most important fruit crop after mango and banana. In Haryana, citrus is grown in an area of about 24,400 ha with a production of 570.88 thousand metric tons and productivity of 23.40 metric tons per hectare (**Indiastat, 2022-23**). Among various citrus species, acid lime (*Citrus aurantifolia* Swingle) originated in India and is commercially grown in tropical and subtropical regions. Acid lime belongs to the family *Rutaceae* and is native to India and South-Eastern China. The lime is called Kagzi in India, which owes its origin to the Indian word kagaj, meaning paper, with which the rind of this fruit is always compared for its thinness. Nutritional and medicinal value are all highly regarded benefits of citrus fruits. It is a rich source of vitamin

C and has good antioxidant properties. Fruits being acidic, they are largely used for garnishing and flavoring several vegetarian and non-vegetarian dishes. Besides its value-added products like pickles, juice, squash, cordials, syrups, lime peel oil, peel powder, etc. are also in great demand in the soap and cosmetic industry (**Debajeet et al., 2011**). It also makes delicious and refreshing cold drinks. Kagzi lime is one of the important fruit crop grown throughout the world. The major kagzi lime-producing countries are China, Mexico, Brazil, and India. India ranks first among major lime-producing countries in the world (**Indiastat, 2022-23**). The total area of lime & lemon in India is 311.9 thousand hectares with a production of 3586.5 thousand metric tons with average productivity of 12.1 metric tons per hectare. (**Indiastat, 2022-23**).

Priming refers to pre-sowing seed soaking treatment with water, chemicals, bio-stimulants, organic formulations etc. It is receiving considerable attention by the scientific community in the last two decades (**Yakhin et al., 2017**). Very little information has been reported on the effects of organic formulations seed priming in fruit crops and there are no reports on appropriate natural or organic seed priming techniques and the subsequent seedling development in acid lime. With the increasing demand for organic fruits, there is a need to evaluate organic seed priming methods. In conventional systems, seed priming is widely used for many crops to accelerate the rate of germination and to improve uniformity in the establishment of the seedlings (**Taylor and Harman 1990; Halmer 2003**). This main aim of this experiment was to evaluate organic formulations seed priming effect on germination and seedling growth of acid lime, to meet the requirements of organic nursery stock production and organic fruit production. The use of organic formulations for abating the seed dormancy and enhance germination & seedling growth of young seedling in various fruit crops has been reported by **Kumaret al. (2020)** observed significant increase in germination, root length, root diameter, number of secondary roots, fresh root weight, dry root weight in ber with treatment of water and cow urine; **Yadav et al. (2018)** reported that water and cow urine has substantial increase in fresh & dry shoot weight, fresh & dry root weight at 150 DAS in custard apple; panchgavya was found to be most beneficial for improving germination percent and took minimum days for germination, height of seedling, number of leaves, stem girth, leaf area, length of tap root, number of roots per seedling, root/shoot ratio, fresh weight of seedling, dry weight of seedling, survival percentage and minimized mortality percentage **Bagule et al. (2013)** & **Desai et al. (2017)** cow urine 10% dipping for 18 hours noted significantly the maximum height of seedling, fresh weight of root, stem diameter, highest fresh shoot weight, highest leaf area at 45 DAS. in papaya; **Vachhaniet al. (2014)** observed substantial increase in germination percentage, seedling length, primary roots, secondary roots, number of leaves, leaf area, & mortality percentage in Khirnee with treatment cowdung slurry; **Jadhav and Deshmukh (2019)** observed noteworthy increase in number of seedlings per seed, primary root length, secondary root length and seedling diameter at 180 DAS in Rangpur lime with cow urine 50 & 100% ; a substantial increase in sprout height, number of leaves, rootstock diameter & height and germination index was observed in mango with amritpani and panchagavya by **Kumaret al. (2008)**; **Patel et al. (2017)** observed significant increase in shoot and root parameter with treatment of beejamruth (3%) in mango. similar results were obtained by **Reshma and Simi (2019)** in mango with cowdung slurry & **Pavithra et al. (2018)** in Suriname cherry with vermiwash (10%); **Tandon et al. (2019)** reported substantial increase in germination and survival percentage in tamarind with cow urine and cowdung slurry.

The farmer of the state show very high enthusiasm for the cultivation of acid lime. Hence, there is a scope for an increase in the area under this fruit crop. In kagzi lime low germination, unbalanced seedling growth, high mortality, and slow growth of seedling in the nursery are among the major problems faced by farmers (**Shant and Rao, 1973** & **Gupta, 1989**).

So, the major problem is the lack of sufficient and healthy seedlings. Its germination percentage is low and it varies between 27-58 percent (Anandam and Singh, 1969) and takes about 3 weeks to germinate (Naik, 1949 and Cheema *et al.*, 1954). However, kagzi lime is commercially propagated through seeds in India as it comes true to type, because of the high degree (39-60%) of nucellar embryony and self-pollination of the hermaphrodite flower rarely results in genetically variable seeds (Salih & Idris, 2018). In plants, propagated through seed, better and quicker germination of seeds and production of maximum number of seedlings are highly essential to meet the increasing demand of the cultivars in the shortest possible time. Therefore, accelerating the rate of germination and growth of lime seedlings has become a top concern for farmers, nurserymen and scientists on a national level to reduce expenditures and time for seedling maintenance.

Materials and methods

1) **Location:** The present experiment was carried out on freshly extracted seeds of acid lime cv. Kagzi in the screen house, Department of Horticulture, College of Agriculture, CCS Haryana Agricultural University, Hisar, India during the year 2020-2021,

2) **Climate:** Hisar is situated at 29°10' N latitude and 75°46' E longitude, with the experimental location situated at 215.2 m above mean sea level. The climate in Hisar is semiarid with hot and dry summers and extremely cold winters. Both maximum and minimum monthly temperatures exhibit a wide range of variations both during summer and winter. During the season of May to June, there is a maximum temperature of around 45°C and a minimum temperature of freezing point accompanied by occasional frost in winter. The total rainfall as well as its distribution in the region is affected by weather patterns. Rainfall is erratic with 20-30% annual variation and 30-50% seasonal variation. Around 80 percent of the annual rainfall (about 450 mm) occurs from July to September. A few showers can also be expected from December to February due to westerly disturbances.

3) **Seed extraction:** The required seed material of acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi for the experiment was collected from experimental orchard, Department of horticulture, CCS Haryana Agricultural University, Hisar. Fully ripened healthy fruits with even size were selected for seed extraction from a single tree. The seeds were properly extracted from the fruits and washed in running water. The seeds were also rinsed in a strainer and gently pushed off with a soft towel to remove the jelly-like coating from the seeds. Then, all extracted seeds were placed in water. Floating seeds were discarded and seeds sink to the bottom of water used for the experiment purpose.

4) Preparations of organic formulations:

a) Beejamrit: 5kg desi cowdung + 5 ltr cow urine + 50 gm chuna + 50 gm field soil. All these constituents are mixed well in 20 litre of water and allowed for 24 hours; 2 times clockwise rotation was given in a day.

b) Cow urine (50%): 50 ml cowurine of desi cow was added to 50 ml distilled water

c) Cow urine (100%): 100 ml cowurine (pure)

d) Fresh cow-dung (desi cow): Cowdung and water was mixed in the ratio of 9:1

e) Cowdung slurry: Cowdung, cowurine & water were mixed in the ratio of (200 g: 200 ml: 2000 ml) and allowed for the fermentation process for 12 hours. After that 24 g jaggery was added and further allowed for fermentation (12 hours).

f) Control (without soaking)

5) **Treatments:** The experiment was laid out in completely randomized design (CRD), with three replications, with 40 seeds per replication. There were six treatments. The treatments were as follows:

T1– beejamrit,

T2 – cowurine 50%,
T3 – cowurine 100%,
T4 – cowdung,
T5 – cowdung slurry,
T6 – control (without soaking).

- 6) **Seed treatments:** Seeds soaked for 24 hours for each treatment and sown in polybags containing media: sandy soil, FYM and coco-peat (2:1:1) (v/v), which were properly filled, labeled with tags and placed as per layout. Seeds were sown by using dibbling method at a depth of 3-4 cm. The intercultural operations like regular watering, weeding, and plant protection measures like spraying of insecticides against caterpillar and leaf miner were taken.
- 7) **Data collection:** The observations on height, diameter and no. of leaves were recorded at monthly interval starting from 90 days after sowing up to 180 days after sowing. The observations as number of seedling emerged per seed, days taken for first & fifty percent seed germination, germination rate and survival percentage were recorded upto 45 days after sowing. The data on number of branches per seedling, leaf area, shoot fresh and dry weight, chlorophyll content, leaf nitrogen content, root length & root diameter, root fresh & dry weight, number of secondary & fibrous roots, dry shoot to root ratio were measured at the end of the experiment 180 days after sowing of seeds at randomly selected five plants in each treatment. The germination rate provides a measure of the time course of seed germination. The number of seedlings emerging daily were counted from day of sowing the seeds in growing media till the germination is complete (upto 45 DAS). Thereafter, germination index (G.I.) was computed by using the formula (**Abdul-Baki and Anderson, 1973**):

$$G.I. = n/D$$

Where, n = number of seedlings emerging on day 'd'

d = day after sowing

The seedling having greater germination index was considered to have more germination rate. The leaf area of five representative plants was measured for each replication in each treatment at 180 days after sowing by laser leaf area meter CI-202 and average value was computed & expressed in cm² per leaf. The chlorophyll content of sixth & seventh leaf from tip of each selected plant was measured by SPAD meter and the average value of each replication was expressed as SPAD value. The sturdiness quotient is the height (h) in centimeters divided by the stem diameter (d) in millimeters (h/d). It reflects the stocky or spindly nature of the seedlings. Although a good indicator of the ability to withstand physical damage in all stock-types, it is of particular importance in container-grown seedlings.

The Dickson quality index - DQI (**Dickson et al., 1960**) is a tool to evaluate seedling quality as a function of total dry matter (TDM), Sturdiness Quotient (SQ), Shoot to Root Ratio (SRR). These two parameters are used to analyse the seedling quality.

$$SQI = TDM/SQ + \text{Root to Shoot ratio}$$

SQI = Seedling Quality Index

TDM = Total Dry Matter (g)

SQ = Sturdiness Quotient

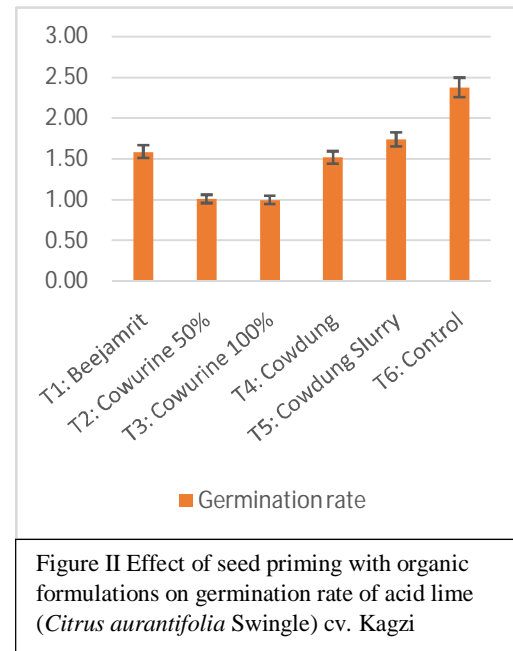
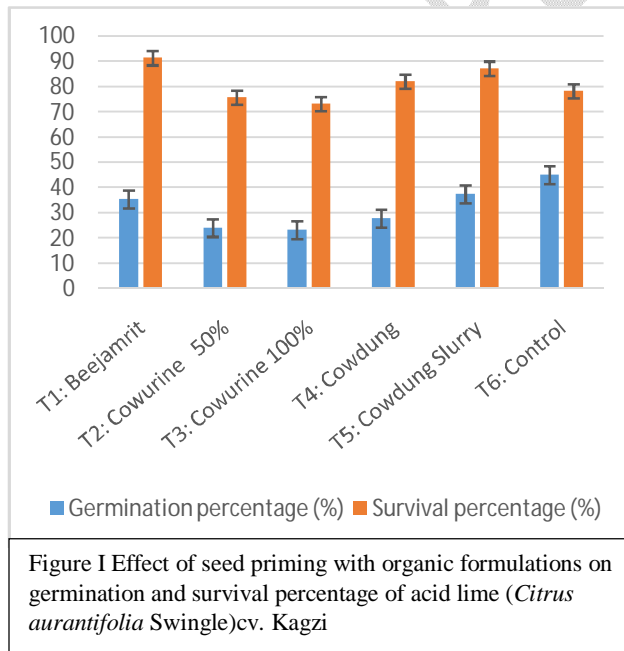
SRR = Shoot to Root Ratio

- 8) **Statistical Analysis:** Analysis of variance (ANOVA) for completely randomized design was done and significant ($P \leq 0.05$) differences between treatments were determined using the least significant difference ($LSD_{0.05}$). The software program used for the analysis was statistical software package for agricultural research workers (**Sheoran et al., 1998**).

Results and discussion

A. Germination parameters

The germination parameters *i.e.* germination percentage and germination rate were significantly influenced by different organic formulations priming treatments. All the treatments found low values of germination parameters over control. The control treatment has substantially more pronounced effect on germination percentage (45.17) and germination rate (2.38). After control, cowdung slurry and beejamrit were at par with each other for all germination parameters. However, the lowest values were obtained under cowurine 100% followed by cowurine 50% (Figure I and II). These results were contrary to earlier findings **Pal *et al.* (2019)** who reported significant increase in germination as compared to control in karonda when treated with cow-urine 25, 50 and 100 percent; **Prajapati *et al.* (2014)** recorded significant upsurge in germination and survival percentage with treatment of cowdung and cowurine; **Vacchaniet *al.* (2014)** using priming treatment cowdung slurry & the significantly early and highest germination percentage were recorded by soaking in cattle urine followed by in cowdung slurry for twelve hours by **Shinde and Malshe (2015)** in Khirni; **Parmar *et al.* (2018)** reported significantly higher germination and survival percentage with treatment of cowdung, cowurine and beejamrit in jack fruit; **Desai *et al.* (2017)** noted significant increase in germination in papaya with application of cowurine; parallel results reported by **Chandel *et al.* (2013)** in mango;



Significant higher germination percentage was observed with priming treatment of cowurine and cowdung paste in Rangpur lime by **Jadhav and Deshmukh (2019)**; **Patel *et al.***

(2017) discovered noteworthy improvement in survival percentage with beejamrit 2% & 3% in mango. The delayed and low germination percentage by the organic formulations was might be due to unknown qualitative and quantitative constituents which causes delayed and poor germination in acid lime. It might be because of unavailability of constituents of organic formulations instantly and becomes available at the later stages of seedling growth.

B. Shoot growth parameters

The shoot growth parameters were significantly influenced by different organic formulations priming treatments. All the treatments found higher values of shoot growth parameters over control, among various treatments highest shoot growth viz. seedling diameter (3.23 mm), seedling height (36.90 cm), leaf area (8.89 cm²) was observed in beejamrit followed by cowdung slurry after 180 days after sowing. The highest number of leaves per seedling (31.67), leaf chlorophyll (33.80 SPAD) & nitrogen content (1.52%) was observed in cowdung slurry followed by beejamrit. beejamrit and cowdung were at par with each other for all shoot parameters (Figure III, IV & VI).

This might be due to build-up of microbial consortia supported by **Patel (1996)** in custard apple and **Chaudhari (2010)** in mango. Seedling growth parameters like number of branches per seedling could not be affected significantly. This might be also possible that increase in colony of microbial consortia, more availability of micronutrients in beejamrit & cowdung slurry due to fermentation process, which supports catalytic, metabolic and hormonal processes. **Parmar et al. (2018)** reported significantly higher shoot growth, seedling height, seedling diameter, number of leaves per plant and leaf area with treatment of cowdung slurry and beejamrit in jack fruit; **Pal et al. (2019)** reported significant increase in shoot growth parameters viz. seedling height, seedling diameter, number of leaves per seedling, leaf area, fresh and dry shoot weight in karonda when treated with cow-urine 50 & 100% in karonda; Analogous results were obtained by **Patel (1996)** in custard apple and in mango by **Chandel et al. (2013)**; **Jadhav and Deshmukh (2019)** noted significant higher number of seedling per seed, seedling height and diameter with cowurine 50% and cowdung paste in Rangpur lime; in suriname cherry significant higher seedling height, number of leaves, seedling girth was reported by **Pavithra et al. (2018)**; **Prajapati et al. (2014)** discovered significant increase in seedling height, seedling diameter, number of leaves per seedling, fresh and dry shoot weight in treatment cowdung and cowurine; **Vacchaniet al. (2014)** recorded significant higher values for shoot growth parameters in cowdung slurry seed priming in Khirnee; All shoot growth parameters were significantly improved with cowurine seed priming by **Desai et al. (2017)** in papaya and also **Bagul et al. (2018)** reported significant higher values for number of leaves per seedling, seedling height, girth of seedling, leaf area, fresh shoot and dry shoot weight in papaya with beejamrit, cowdung slurry and cowurine 50%.

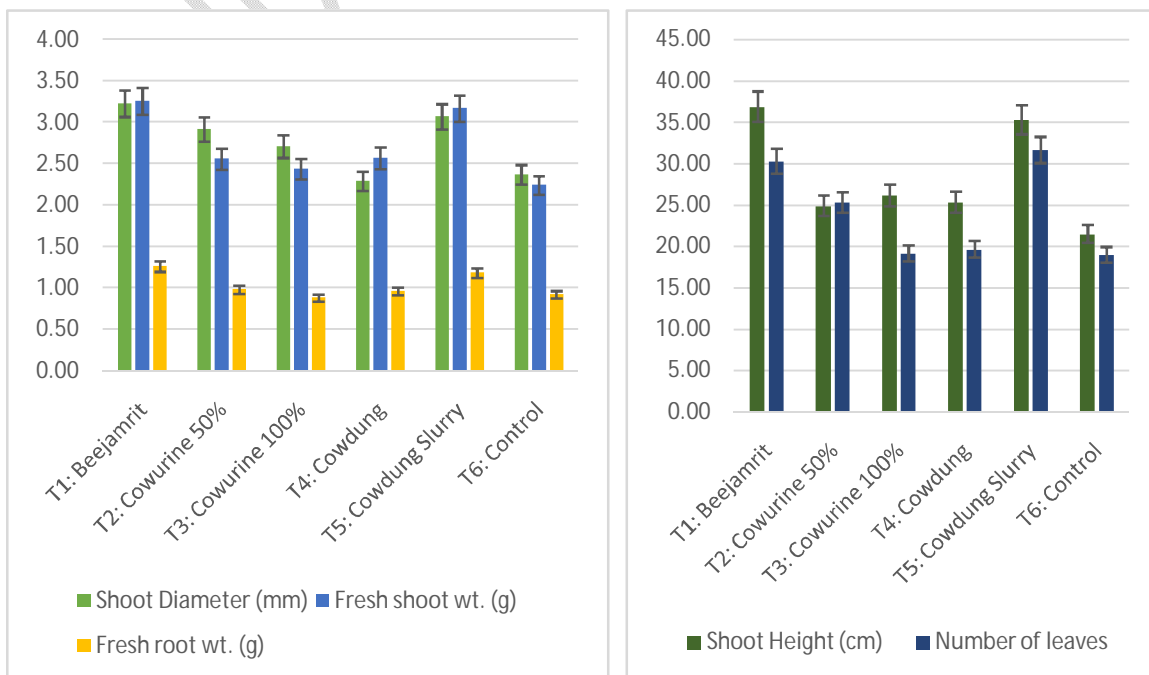


Figure IV Effect of seed priming with organic formulations on shoot height and number of leaves of acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi

C. Root growth parameters

The root growth parameters were significantly influenced by different organic formulations priming treatments. All the treatments found significantly higher values of root growth parameters over control, among various treatments beejamrit found highest root length (37.57 cm), number of secondary roots (50.00), root fresh weight (1.26 g) & dry shoot to root ratio was observed in beejamrit followed by cowdung slurry at 180 days after sowing. Beejamrit and cowdung slurry were statistically at par with each other (Figure III, VI & VII).

Improved seedling root growth was might be due to increased microbial population and more availability of micronutrients in organic formulations due to fermentation process in beejamrit and cowdung slurry which supports catalytic, metabolic and hormonal processes, which helped in re-distribution of photosynthates within the seedling parts and improved root growth. These results are in correspondence with **Vaccani et al. (2014)** who observed significantly effective results in respect of root growth parameters viz. primary root length and no. of secondary roots when seeds were treated with cowdung slurry in khirnee rootstocks; Also **Prajapati et al. (2014)** reported similar results by treating Khirnee rootstock seeds with cowdung, cowurine; Significantly increased root parameters of mango seedling was observed when sown by treating with cowdung slurry by **Reshma and Mini (2019)**; Also analogous results was reported by **Kumar et al. (2008)** & **Chandel et al. (2013)** by treating seed with cowdung,

Figure III Effect of seed priming with organic formulations on shoot diameter, fresh shoot wt. and root wt. growth parameters of acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi

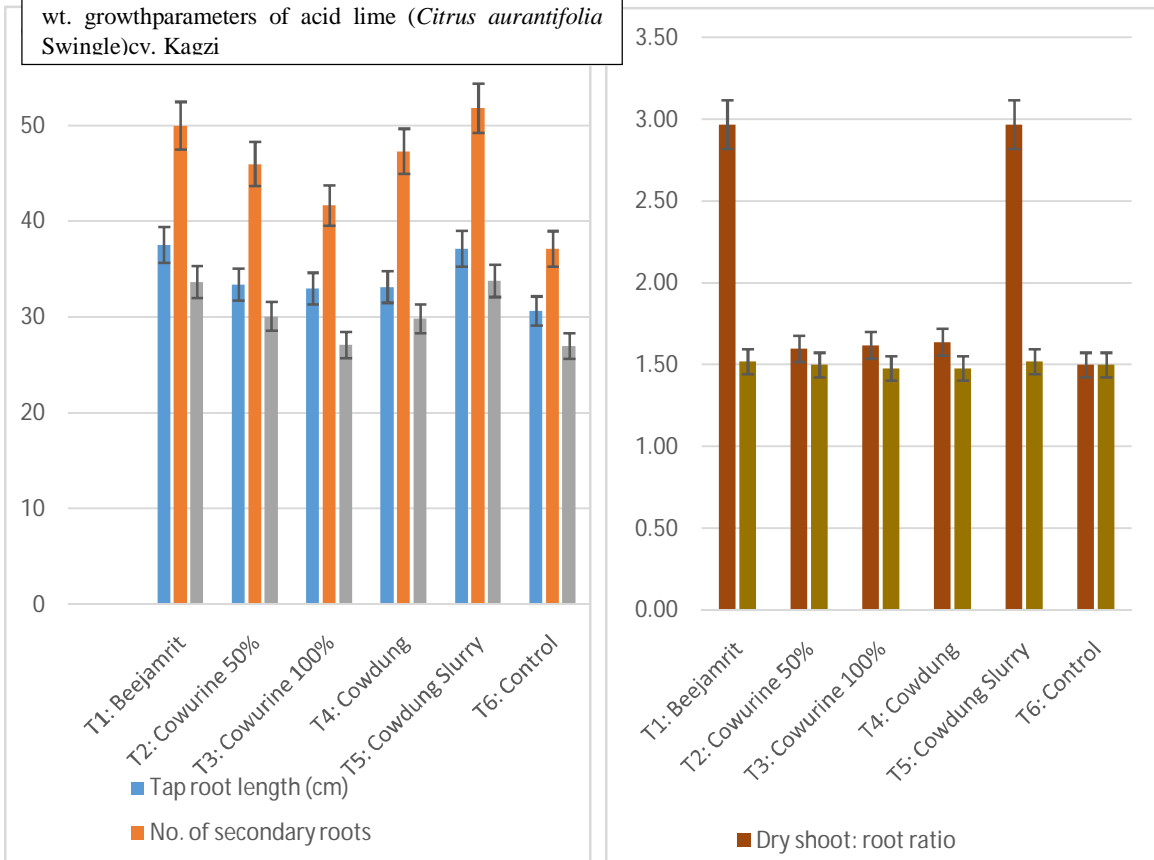


Figure V Effect of seed priming with organic formulations on rootlength, secondary roots and chlorophyll content of acid lime (*Citrus aurantifolia* Swingle)cv. Kagzi

Figure VI Effect of seed priming with organic formulations on dry shoot to root ratio & leaf nitrogen content of acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi

In Rangpur lime, **Jadhav and Deshmukh (2019)** recorded significantly higher primary and secondary root length parameters with cowurine and cowdung paste; **Parmar et al. (2018)** noted maximum number of roots in jack fruitseed primed with cowdung slurry; In papaya **Desai et al. (2017)** & **Bagul et al. (2018)** recorded significant effective results in case of rooting parameters viz. root length, fresh and dry weight of root with cowurine, cowdung, beejamrit and cowdung slurry primed seeds; In tamarind, seed primed with cowurine and cowdung slurry found an effective increase in roots parameters compared to control reported by **Tandon et al. (2019)**.

D. Seedling quality and leaf biochemical parameters

The sturdiness quotient (SQ), seedling quality index (SQI) and leaf chlorophyll content were significantly influenced by different organic formulations. The data on leaf nitrogen content (%) was arithmetical higher in beejamrit and cowdung slurry. The sturdiness quotient is the height (h) in centimeters divided by the stem diameter (d) in millimeters (h/d). It reflects the stocky or spindly nature of the seedlings. Although a good indicator of the ability to withstand physical damage in all stock-types, it is of particular importance in container-grown seedlings. The Dickson quality index - DQI (**Dickson et al., 1960**) is a tool to evaluate seedling quality as a function of total dry matter (TDM), sturdiness quotient and shoot to root ratio. These two parameters are used to analyse the seedling quality. SQ values were significantly highest in cowdung slurry (11.52) and beejamrit (11.42), whereas in case of SQI cowdung slurry (0.178) and beejamrit (0.174).

Chlorophyll content and nitrogen content in leaf was found highest values in cowdung slurry and beejamrit. This might be because of increased microbial population and more availability of micronutrients in organic formulations during fermentation process in beejamrit and cowdung slurry due to fermentation process which supports catalytic, metabolic and hormonal processes, which helped in re-distribution of photosynthates within the seedling parts ultimately improved root growth. These results are in confirmation with **Vacchaniet al. (2014)** who recorded significant higher values for shoot growth parameters in cowdung slurry seed priming in Khirnee; All shoot growth parameters were significantly improved with cowurine seed priming reported by **Desai et al. (2017)** in papaya and also **Bagul et al. (2018)** reported significant higher values for number of leaves per seedling, seedling height, girth of seedling, leaf area, fresh shoot and dry shoot weight in papaya with beejamrit and cowdung slurry.

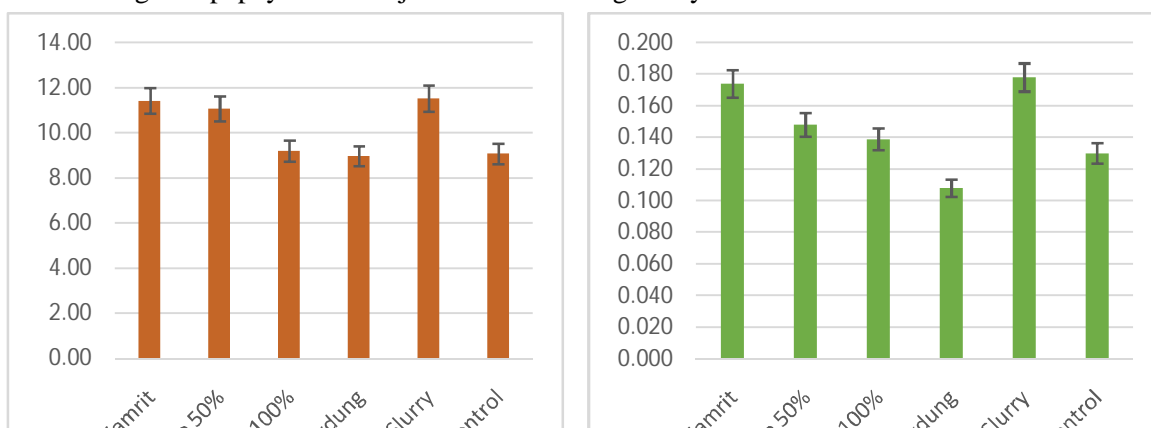


Figure VII Effect of seed priming with organic formulations on sturdiness quotient of acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi

Figure VIII Effect of seed priming with organic formulations on seedling quality index of acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi

The organic formulations seed priming analysis revealed that beejamrit and cowdung slurry have found numerically higher values for the leaf nitrogen content. This might be attributed to the increase in colonies of microbial consortia & better availability of micronutrient, hormones and organic matter content in beejamrit and cowdung slurry.

Conclusion

The appraisal of organic seed priming formulations revealed that sowing of seeds without any organic formulations priming treatment was the most effective method compared to soaking seeds in organic formulations, but soaking of acid lime seeds in beejamrit and cowdung slurry for twenty-four hours was found to be the most successful in promoting shoot and root growth, resulting in higher seedling quality other treatments. The application of beejamrit and cowdung slurry as a seed treatment showed promising results in enhancing shoot and root growth in the organic production of acid lime seedlings. Further investigation into the chemical, physical and microbiological properties of the seed priming treatments is necessary to better understand the underlying causes of these effects. There is potential to further improve acid lime germination by exploring alternative pre-sowing seed treatments.

References

- Abdul-Baki, A. and J. D. Anderson. (1973). Vigor determination in Soybean seed by multiple criteria. *Crop Science*, **13**: 630-633.
- Anandam, R. and Singh R. (1969). Polyembryony in citrus under field condition, *Andhra Agricultural Journal*, **16**(3): 68-7
- Anonymous. (2020). Indian Horticulture Database, www.indiastat.com
- Bagul, H. B., Parmar, A. B., Parmar, B. R., Panday, B. R. and Jnanendra, M. (2018). Effect of pre-sowing seed treatments on germination and growth of papaya (*Carica papaya* L.) seedlings cv. Red Lady. *The Pharma Innovation Journal*, **7**(1): 95-97
- Chadha, K.L. (2010). Handbook of Horticulture. Indian council of Agriculture Research, New Delhi: 209-217
- Chandel N. K., Mishra S. and Prasad V. M. (2013). Influence of panchgavya on germination and growth of mango (*Mangifera indica* L.) stones. *International Bi-Annual Journal of Life Science*, **24**(1): 39-42
- Chaudhari, P. M. (2010). Effect of pre-sowing treatments, sowing position and duration of sowing on germination and growth of mango stones. M.Sc. (Horti.) Thesis submitted to Navsari Agricultural University, Navsari.
- Cheema, G. S., Bhat, S. S. and Naik K. C. (1954). Commercial fruits of India. Macmillan and Co.Ltd: 153-156.

- Debage, P. P., Shinde, E. D. and Ingale, H. V. (2011). Effect of plant growth regulators and nutrients on quality of acid lime (*Citrus aurantifolia*). *Asian Journal of Horticulture*, **6**: 253-55.
- Desai, A., Panchal, B., Trivedi, A. and Prajapati, A. (2017). Studies on seed germination and seedling growth of papaya (*Carica papaya* L.) cv. Madhubindu as influenced by media, GA₃ and cow urine under net house condition. *Journal of Pharmacognosy and Phytochemistry*, **6**(4): 1448-1451
- Dickson, A., Leaf, A. L., & Hosner, J. F. (1960). Seedling quality—Soil fertility relationships of white spruce, and red and white pine in nurseries. *The Forestry Chronicle*, **36**(3): 237-241.
- FAO (2021), Food and Agriculture Organization of the United Nations, Rome, Italy
- Ghosh, S. P. (2000). Citrus industry in Asia. Proceeding international symposium on citriculture, Nagpur (M.S.): 1-23
- Gupta, O.P. (1992). Effect of gibberellic acid on seed germination in lime (*Citrus aurantifolia* Swingle). *Progressive Horticulture*, **21**(3-4): 246-248.
- Jadhav, N. S. and Deshmukh, H. S. (2019). Effect of growth regulators, chemical and organic wastes on the seed germination and seedling diameter of rangpur lime. *Journal of Pharmacognosy and Phytochemistry*, **8**(3): 448-451
- Halmer P. 2003. Methods to improve seed performance. In: Benech-Arnold RL, Sanchez RA, editors. Seed physiology, applications to agriculture. New York (NY): Food Product Press; p. 125–168.
- Kumar, A., Gurjar, P. K. S., Kureel, M. K., Kumar, A. and Asre, A. (2020). Effect of Pre-sowing seed treatments on root growth and survival of ber (*Zizyphus mauritiana* L.). *Journal of Pharmacognosy and Phytochemistry*, **9**(2): 1883-1885
- Kumar, H. S. Y., Swamy, G. S. K., Kanmadi V. C., Prasad Kumar, Sonwmaya, B.N. (2008). Effect of organics and chemicals on germination, growth and graft take in mango. *Asian Journal of Agricultural and Horticultural*, **3**(2): 336-339
- Naik, K. C. (1949). South Indian fruits and their culture, P.Vardachary and Co.:147-149.
- Pal, S., Sharma, T. R., & Nagar, O. P. (2019). Effect of Cow Urine and Plant Growth Promoting Rhizobacteria (PGPR) on Seed Germination, Growth and Survival of Karonda (*Carissa carandas* L.) Seedlings. *International Journal of Current Microbiology and Applied Sciences*, **8**(11): 1967-1978.
- Parmar B. R., Patel F., Parmar A. B. and Panday A. K. (2018). Effect of organic compounds on seed germination and seedling growth of jack fruit (*Artocarpus heterophyllus* Lam.) Seed. *The Pharma Innovation Journal*, **7**(10): 702-704
- Patel, C. B.; Patel, B. N. and Patel, A. N. (1996). A note on seed germination technique for Khirni [*Manilkara hexandra* (Roxb) Dub.]. *Journal of Applied Horticulture*, **2**(1/2): 149-150
- Patel, J. R., Ahlawat, T. R., Patel, A. I., Amarcholi, J. J., Patel, B. B., and Sharma K. (2017). Growth of mango (*Mangifera indica* L.) rootstocks as influenced by pre-sowing treatments. *Journal of Applied and Natural Sciences*, **9**(1): 582-586.
- Pavithra, S., Swamy, G. S. K., Suresh, G. J., Vishnuvardhana, Patil, S. V., and Halesh, G. K. (2018). Effect of growth regulators and chemicals on germination of Surinam cherry (*Eugenia uniflora* L.) Seeds. *International Journal of Current Microbiology and Applied Sciences*, **7**(9): 546-551.
- Prajapati, H.A. (2013). Effect of organics and chemicals on germination and growth of Khirni [*Manilkara hexandra* (Roxb) Dub.] seeds. M.Sc. Thesis submitted to Navsari Agricultural University, Navsari, Gujarat.
- Reshma, U. R., and Simi, S. (2019). Effect of pre-sowing treatments, sowing positions and age of stones after extraction on germination of mango. *International Journal of Current Microbiology and Applied Sciences*, **8**(4): 2565-2573.

- Salih, A. M. M. and Idris, T. M. M. (2018). Germination and post emergence growth of lime (*Citrus aurantifolia* Swingle) as affected by seed priming with growth regulators and bio-stimulants. *Sudan Journal of Science and Technology*, **19**(2).
- Shant, P. S. and Rao S. N. (1973). Note on the effect of gibberellic acid on seed germination and seedling growth of acid lime (*Citrus aurantifolia* Swingle). *Progressive Horticulture*, **5**(3):63-65.
- Sheoran, O. P., Tonk, D. S., Kaushik, L. S., Hasija, R. C., and Pannu, R. S. (1998). Statistical software package for agricultural research workers. *Recent Advances in Information Theory, Statistics and Computer Application*: 139-143.
- Shinde, V. V. and Malshe K. V. (2015). Effect of cattle urine and cow dung slurry as seed treatment on germination and growth of Khirni (*Manilkara hexandra* L.). *Journal of Eco-friendly Agriculture*, **10**(2): 128-130
- Tandon, K., Gurjar, P. K. S., Lekhi, R., and Soni, D. (2019). Effect of organic substances and plant growth regulators on seed germination and survival of tamarind (*Tamarind indica* L.) seedlings. *International Journal of Current Microbiology and Applied Sciences*, **8**(2): 2270-2274.
- Taylor AG, Harman GE. 1990. Concepts and technologies of selected seed treatments. *Annu Rev Phytopathol.* 28:321–329.
- Vachhani, K. B., Gohil, J. H., Pandey, R., and Ray, N. R. (2014). Influence of chemicals, PGR's and cow-dung slurry as seed treatment on germinability, growth and development of Khirni (*Manilkara hexandra* Roxb) under net house condition. *Trends in Biosciences Journal*, **7**(14):1641- 1643.
- Yadav, R. S., Sharma T. R., Panday, S. K. and Maske, G. (2018). Effect of GA3 and cow urine on growth and physiology of custard apple at seedling stage. *The Pharma Innovation Journal*, **7**(7): 395-397
- Yakhin, O. I., Lubyaynov, A.A., Yakhin, I.A., Brown, P.H. (2017). Biostimulants in plant science: a global perspective. *Frontiers in Plant Science*, **7**: 1-3