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Effect of Seed Priming with Plant Extracts and Its Duration on the Growth and Yield of Bitter Gourd (*Momordica charantia* L.)

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ABSTRACT

A research titled "Effect of seed priming on bitter gourd (*Momordica charantia* L.) with plant extracts and priming durations" was carried out at the Horticulture Research Farm, The University of Agriculture Peshawar, Pakistan in the summer season of 2023. The experiment employed a Randomized Complete Block Design (RCBD) with two factors and three replications. The first factor examined various plant extracts (including untreated seeds, distilled water, Moringa leaf extract (MLE) at 30 gL^{-1}, sprouted garlic extract at 20 gL^{-1}, willow twig extract at 50 gL^{-1}, and maize grain extract at 50gL^{-1}), while the second variable explored priming durations of 0 (control), 8, 16, and 24 hours, with 8-hour intervals. Bitter gourd seeds (Cv. Desi Green) were subjected to priming treatments for varying durations. Results demonstrated that both plant extracts and priming duration significantly influenced all evaluated parameters of bitter gourd growth and yield. Seeds treated with MLE at 30 gL^{-1} exhibited superior performance across all metrics, including reduced germination time (6.67 days), highest emergence rate (89.17%), greatest plant height (404.08cm), maximum branch count (10.23 per plant), highest chlorophyll content (50.72 SPAD), earliest flowering (41.00 days) and optimal fruit characteristics (151.68g individual fruit weight, 15.73cm fruit length) resulting in the highest yield (22.65 tons ha^{-1}). Maize grain extract ranked second in effectiveness across all studied parameters. Likewise, seed priming duration also significantly affected all evaluated traits. The 24-hour priming treatment produced the most favorable results, including shortest germination period (7.00 days), highest emergence percentage (86.40%), tallest plants (403.38cm), maximum branch count (9.99 per plant), highest chlorophyll content (50.34 SPAD), earliest flowering (40.87 days), and optimal fruit characteristics (149.27g individual fruit weight, 15.95cm fruit length) leading to the highest yield (22.01 tons ha^{-1}). Unprimed seeds consistently demonstrated the poorest performance compared to all priming treatments. Based on these findings, it is recommended for the bitter gourd growers in Peshawar region to carry out seed priming with MLE at 30 gL^{-1} concentrations for a duration of 24 hours in order to achieve optimal growth and yield outcomes.

INTRODUCTION

Momordica charantia, commonly known as bitter gourd, belongs to the Cucurbitaceae family. Native to tropical Asia, it is widely cultivated across regions such as Pakistan, India, China, Bangladesh, Malaysia, and parts of tropical Africa. Bitter gourd, a climbing vine, can grow up to 5 meters in length and produces alternating leaves with 3 to 7 deeply separated lobes. It blooms yellow flowers, both male and female, and fruits develop between September and November in the Northern Hemisphere (Cao *et al.,* 2014; Liu *et al.,* 2010).

Typically grown as an annual crop, bitter gourd thrives in temperatures ranging from 25°C to 28°C for optimal seed germination. In Pakistan, during the 2020-2021 period, bitter gourd was cultivated on 4,997 hectares, producing 61,727 tons, with Khyber Pakhtunkhwa contributing 11,604 tons from 937 hectares (MINFSR, 2020-2021). Known for its rich nutritional profile, bitter gourd is an excellent source of vitamins A and C, amino acids, antioxidants, folic acid, and essential minerals such as calcium, magnesium, and potassium. It is also low in sugars and high in dietary fiber, proteins, and beneficial compounds. Additionally, it is used in traditional medicine, with various parts like the fruit, seeds, leaves, and roots providing medicinal benefits (Cefalu *et al.,* 2008; Cousens *et* al., 2008; Islam *et al.,* 2011). A 100g serving provides

approximately 19mg of calcium, 296mg of potassium, and 84mg of vitamin C (USDA, 2021). However, heavy metal contamination in soil may reduce crop productivity (Fang *et al.,* 2016).

One of the challenges in bitter gourd cultivation is poor seed germination, often due to the hard seed coat that limits sprouting. Seeds germinate best at temperatures between 25°C and 28°C, and sprouting rates decrease below this range. To improve germination, seed priming has become a common practice, particularly in countries like Pakistan, India, and Bangladesh. Priming involves pre-treating seeds with nutrients or growth regulators to enhance their sensitivity to environmental conditions and promote uniform seedling growth (Harris *et al.,* 2001; Hill, 2004).

In addition to seed priming, natural plant biochemicals can enhance growth. Moringa oleifera, for instance, contains zeatin, a cytokinin that stimulates cell division and root development. Other plants, such as garlic and willow, are used for their growth-enhancing properties. Garlic extract, known for its strong antibacterial and antifungal effects, helps protect plants from harmful microorganisms (Makkar and Becker, 1996; Bianchi *et al.,* 1997). Willow water, rich in indole butyric acid (IBA) and salicylic acid (SA), serves as a natural rooting hormone that accelerates root growth in cuttings (Hill, 2004).

Maize grain extract (MGE) is another promising biostimulant that helps plants cope with environmental stressors such as salinity, nutrient deficiencies, and heavy metal contamination. MGE contains vital phytohormones like gibberellins, cytokinins, and indole-3-acetic acid (IAA), which enhance plant resilience and growth under stress. Studies have shown that MGE increases hormone levels in plants, improving their ability to withstand harsh conditions. Additionally, MGE enhances antioxidant activity, providing further protection against oxidative stress (Rady *et al.,* 2019; Semida and Rady, 2014). It has proven effective in boosting the growth of crops like beans, sunflowers, and wheat, even in nutrient-stressed and contaminated soils (Alzahrani and Rady, 2019).

MATERIALS AND METHODS

The effect of seed priming on bitter gourd (*Momordica charantia* L.) with plant extracts at different priming durations was tested at Horticulture Research Farm, The University of Agriculture Peshawar during summer season of 2023. The study utilized a randomized complete block design (RCBD) with two factors and three replications. The first factor comprised different plant extracts, while the second factor explored various priming durations. The experiment comprised 20 distinct treatments and 60 experimental units. Following two factors were studied in the experiment: Plant extracts, Distilled water. Moringa leaves extract (30g L^{-1}), Sprouted garlic extract (20g L^{-1}), Willow twigs extract (50g L^{-1}), Maize grains extract (50g L^{-1}) and 2nd factor was priming durations (hours) S0= 0 (control), S1=8, S2=16, S3=24.

Statistical Analysis

The collected data were put through the analysis of variance method to find out significant differences among different treatments. The LSD test, on the other hand, was used to find the mean difference at either 5% level of significance (Steel and Torrie., 1997). ANOVA and LSD were found using the statistical software STATISTIX 8.1(Jan *et al*., 2009).

RESULTS AND DISCUSSION

Days to Germination

Examination of plant extract data revealed that seeds treated with Moringa Leaf Extract (MLE) at 30 gL^{-1} exhibited the shortest germination period (6.67 days). In contrast, water-soaked seeds demonstrated the longest germination time (10.35 days).

Regarding priming duration, seeds subjected to a 24-hour treatment showed the quickest emergence (7.00 days). Unprimed seeds exhibited the most extended germination period (10.35 days).

Priming seeds with natural chemicals that help plants grow is known to be a long-term method that speeds up metabolism and makes germination and sprouting happen faster. For example, MLE seed priming shortened the time it took for plants to appear and increased the percentage of plants that emerged in the end (Nouman *et al.*, 2012; Hala and Nabila, 2017).

Maize grain extract (MGE) has been identified as particularly effective for wheat growth, especially under combined stress conditions, with its bioactive components enabling rapid and robust germination following seed priming (Allharby *et al*., 2020).

Soaking seeds for longer periods, like 12-24 hours, can enhance germination rates and expedite emergence (Dhal *et al.,* 2022). Seed soaking duration affects bitter gourd emergence time. Longer durations promote earlier emergence due to sufficient hydration for germination initiation. Longer soaking may shorten days to emergence by causing excess water uptake. Environmental factors and seed characteristics also play roles. Optimal soaking duration can expedite emergence and ensure uniform seedling establishment, enhancing crop productivity (Saleem *et al.,* 2014).

Emergence percentage

Data regarding emergence percentage showed that maximum emergence percentage (89.17) was recorded in seeds primed with MLE at the rate of 30 gL^{-1}. While minimum emergence percentage (79.58) was recorded in water soaked seeds.

Based on the length of time that the seeds were soaked, the highest emergence percentage (86.40) was seen in seeds that were primed for 24 hours. The lowest emergence percentage was seen in seeds that had not been primed.

The main thing that makes sure that seedlings do better generally is a higher sprouting rate. The study's results showed that priming seeds with MLE 1:30 was the best dose and harvested method, as shown by a higher rate of sprouting and better early seedling growth of spring corn. MLE 1:30 may have worked better because moringa leaves contain more nutrients and vitamins. Priming with MLE not only helped seedlings come up faster, but it also made them stronger as shown by longer roots and shoots (Begum *et al.,* 2009).

Bioactive components in maize grain extract (MGE) are thought to speed up seed germination and seedling

emerging, giving seedlings a strong start to their growth under Cd2+ stress. It was better for plant growth and yield when seeds were primed in MGE because the seeds absorbed some biochemical of the MGE, like osmyolytes, which lowered the osmotic potential of seed (Patane *et al.,* 2013), which made seeds better able to soak up more water, which improved the activities of seed germination enzymes and led to better seed germination (Noman *et al.,* 2018).

In general, soaking seeds for a modest amount of time, usually between a few hours and overnight, can help many crops sprout faster (Dhal *et al.,* 2022). The length of time seeds was wet had a big effect on their ability to germinate. Seeds that were soaked in water for 24 hours had the best sprouting rate. In line with what Uche *et al.* (2016) found, these results show that Capsicum annuum plants grow faster and germinate better after 24 hours of hydropriming. This is because the plants take in more water and divide their cells more quickly.

Length of the Vine (cm)

The vine length data indicated that maximum vine length (404.08cm) was observed in seeds subjected to priming with MLE at a concentration of 30g L^{-1}. On the contrary, minimum plant height (394.59cm) was recorded in water soaked seeds.

The recorded data on soaking duration reveals that the highest vine length (403.38cm) was observed in seeds that underwent priming for 24 hours. In contrast, the lowest vine length (393.59cm) was observed in unprimed seeds.

Hydro priming and priming with MLE resulted in the longest shoots, ranging from 1.80 to 1.85 cm showing an increase of up to 14.91%. This contrasts with the shorter shoot length observed in the control group (1.61 cm). These findings where MLE application negatively affects root length in bean and groundnut seedlings were reported by Chris Phiri and Mbewe (2010). Similarly, MLE priming did not significantly affect root length in sorghum and wheat (Phiri, 2010). However, Sarmin, (2014) previously reported an increase in shoot length due to MLE priming, possibly linked to enhanced cellular proliferation in shoot apical meristem after priming (Noor *et al.,* 2016).

Seed priming with maize grain extract has been reported to positively influence the plant height of various vegetable crop and demonstrated that pre-sowing seed treatment with maize grain extract significantly increased the plant height of tomato, cucumber, and bell pepper seedlings (Patane *et al.,* 2013). Hydro priming of vegetable seeds, including cucumber, tomato, and bitter gourd, may positively affect plant height. This method involves soaking seeds in water to initiate the germination process before planting. By hydrating the seeds, hydro priming can enhance germination rates and promote vigorous early seedling growth, which can contribute to increase plant height during the vegetative stage. However, specific effects may vary depending on seed quality, environmental conditions, and other factors (Cheng, 1999). When bell pepper was soaked in water for 24 hours, the shoot length, root length, and plant dry weight were all significantly the greatest. The addition of a stimulating biochemical mostly causes the shoot ends to divide cells more quickly, which leads to an increase in shoot length (Uche *et al.,* 2016).

Number of Branches Plant^{-1}

The number of branches plant^{-1} data show that the highest number of branches plant^{-1} (10.23) was seen in seeds that were primed with 30 gL^{-1} of Moringa Leaf Extract (MLE). On the other hand, the control group had the fewest stems per plant (8.83).

Observations of the duration of priming showed that seeds primed for 24 hours had the most branches plant^{-1} (9.99). On the other hand, seeds that had not been soaked had the fewest stems per plant (7.59).

Moringa Leaf Extract (MLE) applied to seeds led to taller plants with more stems per plant in the E. angustifolia species. Zheng *et al.* (2015) found the same thing in rice, Rehman *et al.* (2014) in wheat, and Afzal *et al.* (2012) in maize.

The improvement observed in both plant height and branch number, compared to the control, can be attributed to an accelerated rate of cell division and elongation in both shoot and root tips. Additionally, the MLE-primed seeds exhibited an earlier emergence, as evidenced by lower values of Mean Emergence Time (MET), a trend noted in studies by Mahmood *et al.* (2010), Culver *et al.* (2012), and Nouman *et al.* (2012).

Table 1

Days to Germination, Emergence Percentage, Length of the Vine, and Number of Branches Plant^{-1} as Affected by Plant Extracts and Time Durations.

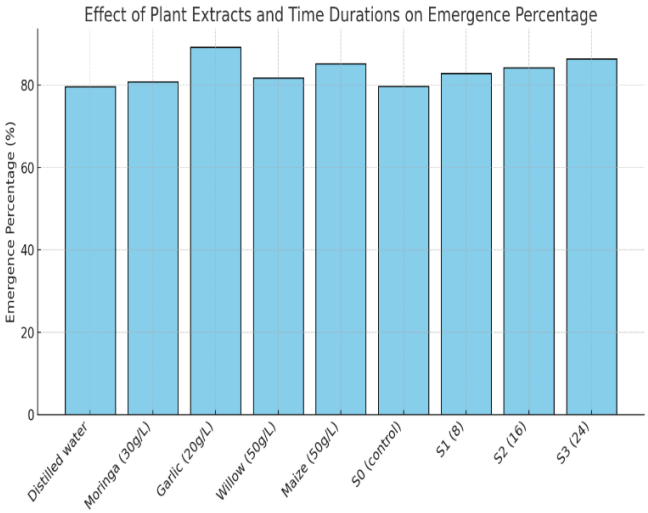
Treatments	Days to germination	Emergence percentage	Length of the vine (cm)	Number of branches plant^{-1}
Distilled water	10.01 a	79.58 e	394.92 e	7.43 e
Moringa leaves extract (30 g L^{-1})	9.17 b	80.75 de	396.05 de	8.03 d
Sprouted garlic extract (20 g L^{-1})	6.67 e	89.17 a	404.08 a	10.23 a
Willow twigs extract (50 g L^{-1})	8.25 c	81.76 d	398.06 cd	8.69 c
Maize grains extract (50 g L^{-1})	7.51 d	85.17 b	400.83 b	9.29 b
S_0 = 0 (control)	10.35 a	79.74 e	393.59 e	7.59 e
S_1 = 8	8.20 c	82.80 c	398.15 cd	8.29 cd
S_2 = 16	7.73 d	84.20 bc	400.03 bc	9.07 b
S_3 = 24	7.00 e	86.40 b	403.38 a	9.99 a
LSD (0.05)	0.55	1.44	2.31	0.33

Mean values followed by distinct letters are significantly different from each other at the 5% level of significance

Maize Grain Extract (MGE) is a promising bio-stimulant for seed priming, containing essential nutrients like phosphorus, potassium, indole-3-acetic acid, and manganese essential for crop growth and the increased number of branches in bitter gourd seeds primed with MGE may be attributed to the availability of phosphorus and other components (Harris *et al.,* 2001); interestingly, while turnip, tomato, and bitter gourd seeds also showed improvements in branching compared to the control group, the effects were relatively moderate which

indicates that the response to hydro priming may vary depending on the species and their inherent physiological characteristics (Harris, 2022). Soaking bitter gourd seeds for the right duration can improve germination rates and lead to stronger root and shoot growth, resulting in healthier branches. Proper soaking can activate enzymes and enhance nutrient absorption, promoting vigorous branching patterns. This contributes to better overall plant health, flowering, and fruiting. Typically, soaking seeds for 12-24 hours is optimal.

Figure 1



Chlorophyll Content (SPAD)

Analysis of plant extract data revealed that seeds treated with Moringa Leaf Extract (MLE) at 30 gL^{-1} exhibited the highest chlorophyll content (50.72 SPAD). In contrast, plants grown from water-soaked seeds showed the lowest chlorophyll levels (41.66 SPAD).

Regarding priming duration, seeds subjected to a 24-hour treatment demonstrated the highest chlorophyll content (50.34 SPAD). The control group (unprimed seeds) exhibited the lowest chlorophyll levels (40.76 SPAD).

The application of MLE, kinetin, or potassium chloride (KCl) has been associated with increased chlorophyll content. Moringa's efficacy in delaying senescence under suboptimal conditions can be attributed to its high content of zeatin, ascorbate, and essential minerals, particularly potassium. This is evidenced in our current study, where priming maize seedlings with Moringa Leaf Extract under chilling stress yielded positive results. The use of SP or a combination of SP and MLE (SP+F) resulted in the highest number of photosynthetically active leaves, indicating delayed senescence and preserved chlorophyll levels during the flowering stage (Basra *et al.,* 2011).

It is worth noting that MGE plays a significant role in enhancing plant physiology under saline conditions, promoting a favorable metabolic state that encourages robust plant growth and development. As highlighted by Talaat (2013), chlorophyll content serves as a crucial physiological indicator, reflecting the plant's photosynthetic capacity. Zhang *et al.* (2015) found that hydro priming and its treatment period had an impact on the overall chlorophyll levels. Their study showed that priming may help avoid significant chlorophyll loss in adverse circumstances. Hydro seed soaking can indirectly boost chlorophyll content in tomato leaves. Soaking for around 24 hours promotes stronger seedlings with better root systems. These healthy seedlings have a greater capacity to absorb nutrients and water. This improved resource uptake enhances chlorophyll production, the green pigment powering photosynthesis in leaves. While soaking duration does not directly create chlorophyll, it sets the stage for optimal production through healthier plant development (Cheng and Bradford, 2021).

Days to 50% Flowering

The data on days to first flowering showed that seeds primed with Moringa Leaf Extract (MLE) at a concentration of 30 gL^{-1} took the fewest days to first flowering (41.00). The water-soaked seeds, on the other hand, took the most days until flowering (47.35).

Comparing the duration for which the seeds were soaked, the seeds that were primed for 24 hours had the fewest days to flower (40.87). The longest period of time (47.35) was seen in seeds that had not been primed.

High sugar levels in seeds primed with moringa leaf extract (MLE) were linked to increased amylase activity, which speeds up the breakdown of starch. Moringa leaf products have been shown to help corn seeds sprout and grow stronger, which backs up the results of this study (Basra *et al.,* 2011).

Primed seeds got off to a strong start, and earlier crop development leads to earlier flowering, which backs up this study findings (Farooq *et al.,* 2006). Earlier and stronger stand might make it easier for crops to compete with weeds and help plants absorb more water and nutrients through their strong roots, which led to more stems, tillers, pods and seeds in pods.

It is possible that maize grain extract (MGE) could help plants flower earlier. The reason could be that MGE has cytokinins, nitrogen, phosphorus, potassium, magnesium, calcium, iron, manganese, and zinc in it. When seeds are ready, they take in water and start their metabolism, which can help them sprout faster and more evenly. In turn, this may help the plant flower earlier in the next growth stages (Afzal *et al.,* 2012). Hydro priming treatment proved to be an effective method for accelerating flowering in vegetable crops, thereby potentially shortening the crop cycle and improving overall yield (Smith *et al.,* 2019).

Fruit Length (cm)

Analysis of the data revealed that the longest fruits (15.73 cm) were produced when seeds were treated with Moringa Leaf Extract (MLE) at a concentration of 30g L^{-1}. In contrast, seeds that underwent water soaking yielded the shortest fruits, measuring 12.61 cm.

Regarding priming duration, seeds subjected to a 24-hour priming period produced the longest fruits, measuring 15.95 cm. while the shortest fruits, measuring 12.57 cm, were observed in unprimed seeds.

Maize grain extract (MGE) contains a diverse array of essential components, including cytokinin, phosphorus, nitrogen, potassium, magnesium, calcium, iron, zinc, and other elements and the development of bitter gourd fruits, particularly in terms of length, may be influenced by nutrients such as phosphorus, potassium, or nitrogen as well as due to presence of PGRs that promote cell division and enlargement (Ghassemi *et al.,* 2008).

Moringa leaf extract is rich in various macro and micronutrients, including potassium, sulfur, zinc, and calcium, which play crucial roles in fruit formation and size. The observed increase in bitter gourd fruit length may be attributed to these nutrients. This finding is corroborated by Shah *et al*. (2011), whose research demonstrated that priming bitter gourd seeds in a 1% SSP (Single Super Phosphate) solution for 24 hours not only improved germination and vegetative characteristics, but also positively affected yield-related parameters, including fruit length and weight. This suggests that the application of specific nutrients, such as phosphorus from the SSP solution, can contribute to overall enhancements in bitter gourd crop attributes, particularly in terms of fruit development.

Various investigations have shown that priming seeds produces bigger and more uniformly formed fruit. The most favorable outcome was noticed when the seeds were soaked at a temperature of 45ºC for a duration of five minutes (Tania *et al.,* 2019). Hydropriming and its soaking duration can influence bitter gourd (*Momordica charantia*) fruit length such that longer hydropriming durations typically led to improved germination and faster seedling emergence, potentially resulting in longer fruit length due to extended growth periods, but, excessively long hydropriming durations may lead to adverse effects such as seed decay or reduced vigor. Finding the optimal hydropriming duration is essential for maximizing fruit length while avoiding negative consequences (Mehta *et al.,* 2014).

Fruit Weight (g)

The heaviest fruit (151.68g) came from seeds that were primed with MLE at a rate of 30g L^{-1}. On the other hand, the seeds that had not been primed produced the lightest fruit (140.49 g).

The seeds that were primed for 24 hours had the biggest fruit weight (149.27g). The smallest fruit weight (140.49g) was seen in seeds that had not been primed.

Chiteka *et al*., (2012) observed a noteworthy correlation, affirming that the utilization of Moringa root and leaf extract as a seed priming agent resulted in a substantial ($p<0.05$) augmentation in both the fresh fruit weight and the proliferation of stems, flowers, and branches in tomato plants, whereas, in addition to this, Reddy *et al.* (1992) established that the effective application of Moringa leaf extract as seed priming agent can enhance fruit setting, overall yield, and the weight of fruits in both tomato and okra crops.

Maize grain extract (MGE) comprises a synergistic blend of vital components including cytokinin, phosphorus, nitrogen, potassium, magnesium, calcium, iron, zinc and different elements such that the maturation of bitter gourd fruits, specifically in relation to their fruits weight, appears to be intricately linked to the presence of phosphorus, potassium, or nitrogen in maize grain extract and the quality and production of bitter gourd are contingent upon the weight of the fruit; Ghassemi *et al.* (2008) found that the weight of bitter gourd fruit was significantly affected by seed priming in phosphate solutions.

Hydro priming treatments have a positive influence on bitter gourd fruit diameter and weight. The observed enhancements suggest that hydro priming can potentially improve bitter gourd yield by promoting better fruit development (Tania *et al.,* 2019). Soaking tomato seeds before hydro seeding can benefit fruit weight, but timing is crucial. Soaking for 12-24 hours plumps the seed and promotes germination with the help of beneficial sugars. This leads to stronger seedlings that take up nutrients better. However, soaking for too long can damage the seeds (Cheng and Bradford, 2021).

Yield (Tonnes ha^{-1})

Table 2 presents the mean yield data for bitter gourd. The findings demonstrate that both the application of plant extracts for seed priming and the duration of the priming process significantly influenced the crop yield of bitter gourd. However, statistical analysis revealed no significant interaction between plant extracts and priming duration.

Examination of the yield data showed that seeds treated with Moringa Leaf Extract (MLE) at a concentration of 30g L^{-1} produced the highest yield (22.65 tonnes). In contrast, unprimed seeds resulted in the lowest yield (20.26 tons).

Regarding priming duration, seeds subjected to a 24-hour priming period demonstrated the highest yield of 22.01 tonnes. The lowest yield (20.34 tons) was observed in the control group of unprimed seeds.

The application of Moringa Leaf Extract (MLE) in early-sown maize has been shown to boost crop yields, mirroring the beneficial outcomes observed when using MLE for seed priming in maize grain production, which enhanced productivity in both cases can be linked to quicker initial seedling development and a prolonged photosynthetic phase, as indicated by the elevated chlorophyll levels detected when the plants reached full maturity (Yasmeen *et al.,* 2013).

Research on *Phaseolus vulgaris* L. has revealed that pre-treating seeds with Maize Grain Extract (MGE) led to significant enhancements in plant growth and yield metrics when cultivated in salt-affected soils, outperforming untreated plants exposed to similar saline conditions; the advantageous impact of MGE seed pre-treatment on plant development is likely due to the rich composition of extract having growth-enhancing compounds and bioactive elements, whereby these constituents seem to activate various growth mechanisms within plant tissues, thereby counteracting the detrimental effects typically associated with high-salinity soil environments (Semida and Rady, 2014).

According to Zhang *et al.* (2015), soaking bean seeds in water before planting, a process known as hydro-priming, enhanced the performance of the seeds in the field. This improvement was seen in several aspects, including a higher percentage of seedling establishment, greater ground cover, increased plant biomass, and better grain production per unit area. Seed priming and its soaking time has the potential to enhance vegetable crop yields by improving germination, early vigor, stress tolerance and uniformity of emergence. However, the effectiveness of priming can vary, and careful consideration of priming techniques and durations is necessary to maximize yield benefits while minimizing risks, but in general seed soaking for longer time can lead to improve production of crops (Rawat, 2020).

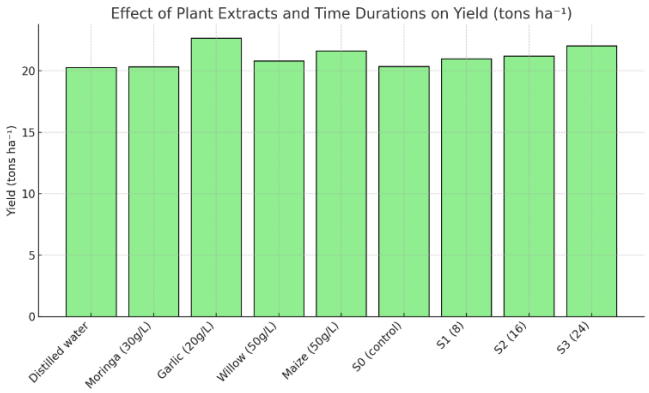
Table 2

Chlorophyll Content, Days to 50% Flowering, Fruit Length, Fruit Weight and Yield Tons ha^{-1} as Affected by Plant Extracts and Time Durations

Treatments	Chlorophyll content (SPAD)	Days to 50% flowering	Fruit length (cm)	Fruit weight (g)	Yield (tons ha^{-1})
Distilled water	41.66 d	46.67 a	12.61 d	140.62 d	20.26 d
Moringa leaves extract (30 g L^{-1})	44.18 c	44.08 b	12.88 d	141.98 cd	20.33 d
Sprouted garlic extract (20 g L^{-1})	50.72 a	41.00 d	15.73 a	151.68 a	22.65 a
Willow twigs extract (50 g L^{-1})	44.48 c	43.60 bc	14.33 bc	144.09 bc	20.79 cd
Maize grains extract (50 g L^{-1})	48.09 b	43.26 c	15.64 a	147.34 b	21.62 b
S_0 = 0 (control)	40.76 d	47.35 a	12.57 d	140.49 d	20.34 d
S_1 = 8	45.10 c	43.73 bc	13.93 c	144.45 bc	20.97 cd
S_2 = 16	47.09 b	42.93 c	14.50 b	146.36 b	21.21 bc
S_3 = 24	50.34 a	40.87 d	15.95 a	149.27 a	22.01 a
LSD (0.05)	2.31	1.87	1.55	1.77	0.98

Mean values followed by distinct letters are significantly different from each other at the 5% level of significance

Figure 2



CONCLUSIONS

MLE-primed seeds exhibited faster emergence, higher germination rates, increased plant height, thicker stems, more branches, greater chlorophyll content, larger fruits, higher fruit count, heavier fruits, increased yield, and earlier flowering and harvesting. A 24-hour priming duration had a substantial impact on all the aforementioned characteristics.

Recommendations

For optimal bitter gourd growth and yield, seed priming with MLE at 30g L^{-1} is advised. A 24-hour seed priming duration is recommended to achieve the best growth and yield results for bitter gourd. Additional research should be conducted to explore the effects of other plant extracts on bitter gourd and various vegetables.

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