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The effects of different seed priming agents on improving emergence, growth, yield and essential oil percentage of purple coneflower (*Echinacea angustifolia* DC.) under field condition

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ABSTRACT

Purple coneflower (*Echinacea angustifolia* DC. var. *angustifolia*) is an important medicinal plant in pharmacological industry. This plant is produced in commercial scale but their seeds exhibit low germination percentages under field conditions. Enhancing seed germination is thus crucial for improving the production of *E. angustifolia*. The influence of Ethephon, Gibberellic acid (GA3) and moringa leaf extract on emergence, growth attributes, yield attributing characteristics and essential oil percentage of purple coneflower (*E. angustifolia*) were investigated. Freshly harvested seeds of *E. angustifolia* were treated with 0.5, 1 and 2 mM of ethephon, 2000 2500 and 3000 mg/L of gibberellic acid (GA3) and 5, 10 and 15% of moringa leaf extract (MLE). Then, seeds were stratified at 4 °C for 4 weeks in light. All the priming treatments were evaluated for the emergence, growth attributes, yield attributing characteristics and essential oil percentage. Among different treatments MLE-priming at 10% could be recommended, as it was the best in terms of final emergence percentage (96%), mean emergence time (4.78 d), α-amylase activity (52.15 IU/mg), total soluble sugars (61.41 mg/g), reducing sugars (54.19 mg/g), plant height (98.82 cm), number of branches (28.36), biological yield (14.08 t/ha) and root yield dry (8.88 t/ha) and essential oil percentage (0.62%). Moringa leaf extract (10%) is recommended as a priming agent to overcome seed dormancy and improve the emergence, growth, yield and essential oil percentage of *E. angustifolia*.

Keywords: Dormancy, *Echinacea angustifolia*, organic-priming, ethephon, gibberellic acid, *Moringa oleifera*

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1 Introduction

Purple coneflower (*Echinacea angustifolia* DC. var. *angustifolia*) is a medicinal and perennial herb belonging to the Asteraceae family, originated in North America and widely used in the pharmaceutical industry (Foster, 1991; Osowski et al., 2000; Wohlmuth et al., 2002; Qu et al., 2004). It has a greater commercial value compared to other *Echinacea* species (e.g., *Echinacea purpurea* or *Echinacea pallida*) (Maggini et al., 2012). One of the major problems facing the *E. angustifolia* large scale production is the poor seed germination. Propagation by seeds is limited by non-deep physiological dormancy, however the seed germination require overcoming dormancy to increase germination (Smith-Jochum and Albrecht, 1987; Feghahati and Reese, 1994). There are various strategies for breaking seed dormancy, including seed priming. Seed priming means control on process of seed hydration during soaking and allows proceeding with metabolic events before sowing without allowing emergence of radicle (Nawaz et al., 2013). Seed priming is a low cost and easy to adapt strategy for overcoming seed dormancy and improving the initiate germination, homogeneous growth of seedlings, field establishment and high yield even under unfavorable environ-

mental conditions (Zheng et al., 2015; Hussain et al., 2018, 2019). The helpful effects of seed priming treatments are directly associated with a change in plant hormone biosynthesis and signaling. Seed priming has been reported to initiate repair of membranes, repair and build up nucleic acids, increased synthesis of proteins and increased the activity of antioxidant enzymes.

Hydro-priming, Hormonal-priming and Organic-priming are the most common priming methods (ur Rehman et al., 2015). Hydro-priming i.e. seed soaking in pure water and re-drying to original moisture content before sowing (Harris et al., 2001), Hormonal-priming i.e. soaking of seeds in different plant growth regulators (GA3, NAA, etc) (Manoharlal and Saiprasad, 2019) and Organic-priming i.e. seed imbibition together with medicinal and ornamental plant extracts such as, Moringa (*Moringa oleifera* L.) (Afzal et al., 2012; Wajid et al., 2021).

The objective of this research is to improve the productivity of crops through noninvasive and environment friendly organic-priming treatments such as moringa leaf extract (MLE). MLE priming is one of the most effective treatments for improving emergence, growth, and yield of crops (Basra et al., 2011; Khan, 2017; Khan et al., 2020; Ahmed et al., 2021; Ahmed and El-Mahdy, 2022). The effectiveness of MLE priming is due to the fact that its leaves are good source of minerals, vitamins, proteins, amino acids, phenolies, growth hormone (zeatin) and many other compounds that are known for their growth-promoting potential, which enhances the seed emergence and seedling establishment related metabolism (Basra et al., 2011; Khan, 2017; Khan et al., 2020; Yap et al., 2021). Mvumi et al. (2013) reported that the applications of moringa leaf extract at 0.03% increased the yield of beans (*Phaseolus vulgaris*) and maize (*Zea mays*) under field conditions. Thomas and Howarth (2000) also reported that application of MLE extract whereas it is rich with cytokinin (zeatin) and this may be induced cytokinin bio-synthesis in turned maximum number of photosynthetic active leaves and that is obvious from number and area of leaves per plant maintaining the chlorophylls in higher concentrations which reflect on crop yield.

To our best knowledge, there are very little work have been done on the effect of moringa leaf extract priming on germination, seedling growth and yield of medicinal and ornamental plants (Reddy et al., 2020). However, the available data of the effect of seed priming with moringa leaf extracts on germination, seedling growth and root yield of *E. angustifolia* are not available in the literature. Therefore, the present study was conducted to investigate into the effect of moringa leaf extract priming on emergence, growth attributes, yield attributing characteristics and essential oil percentage of *E. angustifolia* under field conditions.

2 Materials and Methods

2.1 Experimental site

The study was conducted at Baramoon Experimental Farm of the Horticulture Research Institute (HRI) in Dakahlia Governorate. This location, in north Egypt, has typical Mediterranean-type climatic conditions (31.05°N, 31.38°E and altitude of 2.89 m. above sea level). Average annual maximum, minimum temperatures and average annual rainfall at this site in 2020 and 2021 were 45.07 °C, 2.32 °C, and 138.88 mm, respectively. The physical and chemical characteristics of the experimental soil are shown in Table 1which was done according to the methods described by Black et al. (1982) and Jackson (1973).

2.2 Seed materials

The seeds of *E. angustifolia* obtained from Division of Agriculture and Biology Research, Department of Ornamental Plants & Woody Trees, National Research Centre, Giza, Egypt were used as research material.

2.3 Preparation of moringa leaf extract

Fresh leaves harvested from fully matured *M. oleifera* trees were air-dried, grinded and extracted. For extraction, ethyl alcohol 80% was added to leaf powder and the mixture was put for 4 hours on a Rotary Shaker (Makkar and Becker, 1996). Extract was purified by filtering twice through Whatman No. 2 filter paper. After purification, the extract was subjected to a Rotary Evaporator to fully evaporate the alcohol. Centrifugation at 8,000 × g for 15 min was then conducted for supernatant. Supernatant was diluted with distilled water at a three concentrations (5, 10 and 15%). The extract or the solution prepared was stored at 0 °C prior to further experiments. The air dried moringa leaves were analyzed for their nutrient contents i.e. total phosphorous, potassium, calcium, magnesium, copper, iron, manganese and zinc (Ryan et al., 2001). The fresh moringa leaves were used for determination of amino acid and vitamin according to Moore and Stein (1954). Determination of indole acetic acid (IAA), gibberellin, were carried out according to the method described by Shindy and Smith (1975). Cytokinin was determined according to Muller and Hilgenberg (1986) method. Total phenolics, α-tocopherol, total flavonoids and epigenin were determined according to the methods described by Ozturk et al. (2007), Carpenter (1979), Rajanandh and Kavitha (2010) and Leone et al. (2015), respectively.

2.4 Seed priming and planting

The priming solutions (Hydropriming with distilled water (DW), Ethephon at 0.5, 1 and 2 mM, Gibberellic acid (GA3) at 2000, 2500 and 3000 mg/L and moringa

Table 1. Mechanical and chemical analyses of the experimental soils at the beginning of experiment in 2020

Properties	Values	Properties	Values
Sand (%)	27.6	Ca_2^+ mg/kg soil	324.1
Silt (%)	31.7	K^+ mg/kg soil	421.2
Clay (%)	40.7	Na^+ meq/L	13.92
Texture class	Clay loam	Mg_2^+ mg/kg soil	1103
Organic matter (%)	1.09	P mg/kg soil	3.36
$CaCO_3$	17.5	Cl^- meq/L	17.64
pH (1:2.5 extract)	7.8	SO_4^- meq/L	39.15
E.C. (dS/m)	1.5	Zn mg/kg soil	0.99
Total N mg/kg soil	99.8	Fe mg/kg soil	24.52

leaf extracts at 5, 10 and 15% were prepared and seed of *E. angustifolia* were soaked in various priming solutions (24 h, 25±5 °C and light). Treated seeds were washed three times with DW and stratified at 4 °C for 4 weeks in light. After stratifying, α-amylase activity, total soluble sugars and total reducing sugars were determined in *E. angustifolia* seed sample (0.1 g). In the experiment, fifty seeds of *E. angustifolia* per treatment were sown in the field on mid February of 2020 and 2021 in beds (1×1 m^2) containing two rows (50 cm in between) each row contained two hills (45 cm apart). Soil was directly irrigated to provide suitable moisture for growth. The normal cultural practices for growing *E. angustifolia* plants were conducted as recommended by Ministry of Agricultural and Land Reclamation.

2.5 Experimental design

The experiment was arranged in randomized complete block design (RCBD) with eleven treatments including control, every treatment was replicated five times. The details of treatments are as following: Control (non-priming) (T1), Hydro-priming with distilled water (T2), Ethephon 0.5 mM (T3), Ethephon 1 mM (T4), Ethephon 2 mM (T5), Gibberellic acid (GA3) 2000 mg/L (T6), Gibberellic acid (GA3) 2500 mg/L (T7), Gibberellic acid (GA3) 3000 mg/L (T8), Moringa leaf extracts 5% (T9), Moringa leaf extracts 10% (T10), and Moringa leaf extracts 15% (T11).

2.6 Measurements

2.6.1 Biochemical analysis

α-amylase activity and total reducing sugars were determined in *E. angustifolia* seed sample (0.1 g), according to the modified DNS method (Varavinit et al., 2002). Total soluble sugars were quantified according to the method of Thimmaiah (2004).

2.6.2 Emergence attributes

Mean emergence time (MET) was calculated as follows:

$$MET = \sum_{i=1}^{N} n_i \times d_i \quad (1)$$

where, n_i = number of seed germinated on i^{th} day (d_i), and N = total days of observation. The lower MET, the faster a population of seeds has emerged (Ellis and Roberts, 1981).

The number of emerged seeds (hypocotyl arch visible) was counted until the final seed emerged and following parameters were recorded. Emergence was counted on daily basis until a constant count achieved. Final emergence percentage (FEP) was calculated as follows:

$$PEP\ (\%) = \left(\frac{N_G}{N_T}\right) \times 100 \quad (2)$$

where, N_G = total number of seeds germinated, and N_T =total number of seeds used (Mitchell and Vogel, 2012).

2.6.3 Morphology, yield traits and essential oil

Before harvesting of plants, plant height (cm) (include the inflorescence stalk) and number of branches/plant were measured on ten plants in each treatment. At harvest time (end of the flowering stage), randomly samples of plants were taken (ten plants per treatment) to assess yield attributing characteristics and essential oil percentage. Dry weight of whole plant and roots were measured. Harvested plants were air dried at room temperature (less than 25 °C). Under this experimental condition, 14 days typically was required based on decrease of herb weight (12% humidity in herb) to complete the drying process. Essential oils (EO) were extracted by a water distillation method using a Clevenger-type. About 100 g of dried roots from different treatments was put in a 2 L flask and hydro distillated for 4 hrs (EP, 2005). The amount of essential oil (%) obtained from the

dried roots of *E. angustifolia* was calculated according to the following formula:

$$EO\ (\%) = \frac{A}{B} \times 100 \quad (3)$$

where, A is the quantity of the essential oils from dried roots sample (mL), and B is the weight of the dried roots sample (g).

2.7 Data analysis

The collected data were analyzed statistically by using analysis of variance (ANOVA) with SPSS 22.0 (SPSS, Inc., USA) software. The treatment means were compared by Dunckun's Multiple Range Test (DMRT) at 5% level of significance (Duncan, 1955).

3 Results

3.1 Moringa leaf composition

Table 2 showed the results of proximate analysis of moringa leaves. The results revealed that moringa leaves are good sources of essential macro and micro nutrients such as Ca, Mg, K, P, Fe, Mn, Cu and Zn, free amino acids, vitamins and phytohormones such as Gibberellin, Zeatin and Indole acetic acid (IAA).

3.2 Emergence attributes

Different seed priming treatments significantly ($P \leq 0.05$) improved the emergence attributes of *E. angustifolia* compared with non-primed seeds. Moringa leaf extract treatments was recorded as the best priming agent for efficiently improving emergence attributes in *E. angustifolia* followed by gibberellic acid, as compared to the other priming agents. Lowest values of mean emergence time (MET) and highest final emergence percentage were recorded for seeds primed with moringa leaf extract (10%) while control treatment took maximum time to emerge and exhibited lowest final emergence percentage (Table 3). The maximum (22 d) and minimum (4.78 d) mean emergence time was taken by control and moringa leaf extract (10%), respectively. The maximum (96%) and minimum (12%) final emergence percentage were recorded in moringa leaf extract (10%) and control, respectively.

3.3 Biochemical analysis

Result of biochemical analyses revealed a significant ($P \leq 0.05$) increase in α-amylase activity, total soluble sugars, and reducing sugars (Table 4). MLE followed by gibberellic acid, ethephon and distilled water treatments significantly increased α-amylase activity, total soluble sugars and reducing sugars in *E. angustifolia* primed seeds. However, control treatment showed minimum values for both these parameters (Table 4).

3.4 Growth attributes

The data presented in Table 5 revealed that all growth attributing (plant height and number of branches/plant) of *E. angustifolia* significantly ($P \leq 0.05$) affected by priming treatments. The seed primed with moringa leaf extract (MLE) produced significantly taller plants than all other treatments and it was followed by gibberellic acid, ethephon and distilled water treatments (Table 5). The control treatment produced significantly shorter plants than all priming treatments. Within the priming agents the distilled water treatment produced shortest plant. Similarly to plant height, the maximum number of branches per plant (28.36) was recorded when seeds were primed with moringa leaf extract (10%). MLE treatments were followed by gibberellic acid, ethephon and distilled water treatments Table 5. The minimum number of branches per plant (2.42) was recorded in control treatment.

3.5 Yield characters and essential oil content

Data in Table 6 showed the effect of seed priming treatments on biological yield and root yield dry of *E. angustifolia*. Different seed priming treatments significantly ($P \leq 0.05$) improved the biological yield and root yield dry of *E. angustifolia* compared with non-primed seeds. MLE priming treatments were superior over gibberellic acid, ethephon and distilled water treatments in the contents of biological yield and root yield dry. The maximum values (14.08 t/ha and 8.88 t/ha) of biological yield and root yield dry were recorded in moringa leaf extract (10%) and control, respectively. The minimum values (1.24 t/ha and 0.78 t/ha) of biological yield and root yield dry were recorded in control, respectively.

According to the results, seeds priming treatments had marked effects on the essential oil percentage of *E. angustifolia* (Table 6). Application of MLE significantly increased the essential oil percentage. 10% MLE priming treatment produced the highest amount of essential oil (0.62 %) in roots.

4 Discussion

Seed priming has presented promising and even surprising results for many seeds including wheat (Ahmed et al., 2021), maize (Ahmed and El-Mahdy, 2022), sunflower (Hussain et al., 2006), rice (Zheng et al., 2015), linseed (ur Rehman et al., 2014) and range grasses i.e. *Cenchrus ciliaris*, *Panicum antidotale* and *Echinochloa crusgalli* (Nouman et al., 2012). The direct

Table 2. Chemical composition of *Moringa oleifera* leaves

Component	2020 season	2021 season
Amino acids (mg/100 g)	156.7	167.9
Protein (g/100 g)	7.72	6.4
Arginine (mg/100 g)	409.6	403.1
Histidine (mg/100 g)	159.8	144.2
Isoleucine (mg/100 g)	299.8	289.3
Leucine (mg/100 g)	494.2	491.4
Lysine (mg/100 g)	343.4	344.1
Methionine (mg/100 g)	117.7	113.3
Phenylainine (mg/100 g)	310.3	311.2
Threonine (mg/100 g)	119.7	115.6
Tryptophan (mg/100 g)	108	104
Valine (mg/100 g)	374.5	376.1
Calcium (mg/g)	9.65	10.12
Magnesium (mg/g)	7.19	8.65
Potassium (mg/g)	29.34	32.76
Phosphorus (mg/g)	7.321	8.432
Sodium (mg/g)	0.432	0.543
Iron (mg/g)	1.56	1.87
Manganese (mg/g)	0.98	1.45
Zinc (mg/g)	0.56	0.65
Copper (mg/g)	0.32	0.34
Vitamin A (mg/100 g)	6.78	6.18
Vitamin B1 (mg/100 g)	0.06	0.07
Vitamin B2 (mg/100 g)	0.05	0.06
Vitamin B3 (mg/100 g)	0.8	0.84
Vitamin C (mg/100 g)	444.7	467.2
Indole-3- acetic acid (µg/g DW)	0.87	0.9
Gibberellins (mg/g)	0.902	0.92
Zeatin (mg/g)	0.94	0.99
Abscisic acid (mg/100 g)	0.27	0.26
Total polyphenol (mg/g)	28.05	27.7
Total flavonoid (mg/g)	80	81
Total tocopherol (µg/g)	7	6
Total apigenin (µmol/g)	10.52	11.3
Fat (g/100 g)	1.7	1.9
Carbohydrate (g/100 g)	12.5	12.9

benefits of seed priming in all crops are faster emergence, more and uniform stands, less need to resow, more vigourous plants, earlier harvest and higher yield (Zheng et al., 2015; Hussain et al., 2018, 2019).

The study results demonstrated that moringa leaf extract (MLE) pretreatment significantly improved the seed emergence, growth attributes, yield contributing characters and essential oil percentage of *E. angustifolia*. These results are in agreement with those of Ahmed et al. (2021) in wheat, Ahmed and El-Mahdy (2022) in maize, Zheng et al. (2015) in rice and Nouman et al. (2012) in range grasses.

The effects of MLE were more pronounced in synchronizing emergence as exhibited in low mean emergence time (MET) and higher final emergence percentage of *E. angustifolia*. Improvement of emergence in *E. angustifolia* seeds by MLE treatments might be because of changes in seed phytohormone contents particularly reduction of abscisic acid content, improvement of antioxidant capacity that stimulated emergence (Mildažienė et al., 2019; Afzal et al., 2020a). An improvement in emergence attributes potential by the influence of moringa leaf extract in the seeds of wheat (Ahmed et al., 2021), maize (Ahmed and El-Mahdy, 2022), linseed (ur Rehman et al., 2014) and range grasses Nouman et al. (2012) had also been reported.

Seed priming with MLE increased plant height and number of branches/plant of *E. angustifolia*. Similar results were reported by Zheng et al. (2015) in rice, ur Rehman et al. (2014) in linseed and Afzal et al. (2012) in maize. Improvement in plant height and number of branches/plant of MLE primed seeds as compared to control is due to an increased rate of cell

Table 3. Effect of seed priming treatments on mean emergence time (MET) and final emergence percentage of *E. angustifolia* (pooled data of 2020 and 2021 seasons)

Treatments	Mean emergence time (MET) (day)	Final emergence percentage (%)
Control (non-Priming)	22.00a	12f
Hydro-priming with DW†	21.55a	28def
Ethephon (0.5 mM)	16.28b	38cde
Ethephon (1 mM)	13.81d	52de
Ethephon (2 mM)	15.45c	42de
Gibberellic acid (2000 mg/L)	13.44d	54bc
Gibberellic acid (2500 mg/L)	11.00f	60b
Gibberellic acid (3000 mg/L)	12.18e	56bc
Moringa leaf extracts (5%)	8.53g	84a
Moringa leaf extracts (10%)	4.78i	96a
Moringa leaf extracts (15%)	6.90h	86a

Means in the same column that do not share a letter are significantly different at 5% level of significance according to the Dunckun's Multiple Range Test (DMRT); †DW: distilled water

Table 4. Effect of seed priming treatments on biochemical attributes of *E. angustifolia* seeds after priming

Treatment	α-amylase specificity (IU/mg)	Total soluble sugars (mg/g)	Reducing sugars (mg/g)
Control (non-Priming)	10.17 g	16.44 g	9.15 g
Hydro-priming with DW†	17.71 f	20.55 f	14.53 f
Ethephon (0.5 mM)	21.81 ef	27.19 ef	20.67 ef
Ethephon (1 mM)	25.11 e	30.17 e	25.13 e
Ethephon (2 mM)	24.17 ef	29.21 ef	23.51 ef
Gibberellic acid (2000 mg/L)	30.19 d	43.16 d	33.16 d
Gibberellic acid (2500 mg/L)	36.13 c	44.32 c	38.61 c
Gibberellic acid (3000 mg/L)	34.17 cd	46.52 cd	36.73 cd
Moringa leaf extracts (5%)	43.12 bc	54.43 bc	46.28 bc
Moringa leaf extracts (10%)	52.15 a	61.41 a	54.19 a
Moringa leaf extracts (15%)	45.17 b	56.11 b	49.13 b

Means in the same column that do not share a letter are significantly different at 5% level of significance according to the Dunckun's Multiple Range Test (DMRT); †DW: distilled water

Table 5. Effect of seed priming treatments on plant height and number of branches per plant of E. angustifolia (pooled data of 2020 and 2021 seasons at harvest)

Treatment	Plant height (cm)	Number of branches/ plant
Control (non-Priming)	52.34 h	2.42 i
Hydro-priming with DW†	60.00 gh	4.20 h
Ethephon (0.5 mM)	61.80 g	5.68 gh
Ethephon (1 mM)	65.06 ef	7.84 ef
Ethephon (2 mM)	66.80 f	6.48 fgh
Gibberellic acid (2000 mg/L)	75.82 de	8.74 fg
Gibberellic acid (2500 mg/L)	78.70 d	10.38 cd
Gibberellic acid (3000 mg/L)	76.20 de	9.26 de
Moringa leaf extracts (5%)	88.80 c	19.84 c
Moringa leaf extracts (10%)	98.82 a	28.36 a
Moringa leaf extracts (15%)	93.20 b	21.28 b

Means in the same column that do not share a letter are significantly different at 5% level of significance according to the Dunckun's Multiple Range Test (DMRT); †DW: distilled water

Table 6. Effect of seed priming treatments on yield characters and oil content of *E. angustifolia* (pooled data of 2020 and 2021 seasons at harvest)

Treatment	Biological yield (t/ha)	Dry root yield (t/ha)	Essential oil (%)
Control (non-Priming)	1.24 h	0.78 g	0.17 k
Hydro-priming with DW†	3.06 g	1.93f g	0.20 j
Ethephon (0.5 mM)	4.18 fg	2.64 ef	0.24 i
Ethephon (1 mM)	6.06 e	3.82 cde	0.29 g
Ethephon (2 mM)	4.69 f	2.96 def	0.27 h
Gibberellic acid (2000 mg/L)	6.35 e	4.00 cd	0.33 f
Gibberellic acid (2500 mg/L)	7.29 d	4.59 c	0.41 d
Gibberellic acid (3000 mg/L)	6.63 e	4.18 c	0.37 e
Moringa leaf extracts (5%)	11.18 c	7.05 b	0.54 c
Moringa leaf extracts (10%)	14.08 a	8.88 a	0.62 a
Moringa leaf extracts (15%)	11.89 b	7.49 b	0.57 b

Means in the same column that do not share a letter are significantly different at 5% level of significance according to the Dunckun's Multiple Range Test (DMRT); †DW: distilled water

division and cell elongation in the shoot and root tips and earlier start of emergence as indicated by lower values of MET (Mahmood et al., 2010; Culver et al., 2012; Nouman et al., 2012).

Improved plant growth by seed priming with MLE in present study could be attributed to enhanced α-amylase activity stimulating starch metabolism as reported by high sugar levels in MLE primed seeds (Radjabian et al., 2007; Afzal et al., 2012, 2015). Another explanation for improved plant growth might be due to moringa leaf extract composition being rich in zeatin, phenolics, antioxidants and minerals and other growth enhancing components (Table 2). Earlier and vigorous stand might increase absorption of water and nutrients by vigorous root system, and thereby produced increased number of branches.

Higher emergence rate with reduced mean emergence time are the main contributors, which ensures an improvement of overall seedling performance, plant growth rate and yield related traits (Afzal et al., 2020b). In the present study seed enhancements not only speed up emergence but also improved final emergence, plant growth rate and net assimilation rate, which ultimately contributed to improved biological yield and root yield dry of *E. angustifolia*.

All the seed priming treatments have positive effects on biological yield, root yield dry and essential oil percentage in *E. angustifolia*. However, maximum biological yield, root yield dry and essential oil percentage were observed in plants raised from MLE primed seeds. Improved essential oil percentage by MLE treated seeds as compared to non-primed seeds seems to be the result of biological yield and root yield dry which is the outcome of energetic start by early and improved emergence of MLE primed seeds and high plant growth rate. Incremental effects of moringa leaf extract priming treatments have been observed on yield and essential oil percentage of rose-scented geranium (*Pelargonium graveolens* L) (Ali et al., 2018).

5 Conclusion

In conclusion, treatment moringa leaf extract priming found the most effective for emergence percentage, growth attributes and essential oil percentage of *E. angustifolia* plants under field conditions, that treatment is the most recommended for overcoming seed dormancy and improving the initiate germination, homogeneous growth of seedlings, field establishment and high yield and essential oil percentage of *E. angustifolia* under our experimental conditions. However, further studies are recommended to elucidate the phytochemical constituents of MLE and the mode of action of this extract in overcoming seed dormancy of *E. angustifolia*.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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