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Improvement of Seed Germination in Three Medicinal Plant Species by Plant Growth Regulators

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Abstract. **Peppermint (*Mentha piperita*), sweet basil (*Ocimum basilicum*), and coriander (*Coriandrum sativum*) are important medicinal plants in the pharmacological industry. These plants are produced in commercial scale but their seeds exhibit low germination percentages under favorable germination conditions. Enhancing seed germination is thus crucial for improving the production of these plants. The influence of gibberellic acid (GA_3), indole-3-acetic acid (IAA), indol-3-butyric acid (IBA), and naphthalene acetic acid (NAA) on seed germination of the three plants were investigated. The seeds were soaked in each plant growth regulator at 50, 100, and 150 mg·L^{-1} for 24 hours at 25 ± 2 °C. Seed germination was checked daily for 20 days and germination parameters including final germination percentage (FGP), corrected germination rate (CGRI), and number of days lapsed to reach 50% of FGP (GT_{50}) were recorded. The phosphorus and protein contents were determined in germinated seedlings on day 21 of culture. All plant growth regulators enhanced seed germination as compared with control. However, GA_3 improved seed germination more than IAA, IBA, and NAA. GA_3 at 100 mg·L^{-1} significantly increased the FGP from 22.3% and 33.3% (control) to 74% and 65.6% for peppermint and sweet basil, respectively. Low concentration of GA_3 at 50 mg·L^{-1} increased the FGP for coriander from 27% to 52.3%. GA_3 also increased CGRI, GT_{50}, phosphorus, and protein contents in germinated seedlings as compared with control. Seeds of peppermint, sweet basil, and coriander possess a physiological dormancy that could be elevated by GA_3 presowing treatment. This study established a successful methodology for optimizing seed germination to satisfy the demand for the medicinal parts of these plants in the pharmacological industry.**

The study of seed germination of medicinal plant species has received special attention from the scientific community due to the increased demand for these plants in the pharmacological industry, coupled with the need to make rational crops for the production of herbs (Hassan, 2012; Pereira, 1992; Sajjadi, 2006). High seed quality and seedling establishment are the cornerstones of profitable, efficient, and sustainable crop production (Finch-Savage, 1995). Seed dormancy is defined as the failure of an intact viable seed to complete germination under favorable conditions and is controlled by several environmental factors such as light, temperature, and the duration of seed storage (Macchia et al., 2001). Dormancy is an important component of physiological seed quality and so plants with a long history of domestication and plant breeding generally have lower seed dormancy than wild or more recently domesticated species (Copeland and McDonald, 2001). Depending on the plant species and type of dormancy, various methods like scarification, pretreatment with plant growth regulators (PGRs), and temperature shocks are used to break dormancy (Copeland and McDonald 2001; Hidayati et al., 2012).

Plant seed germination depends on both intrinsic and extrinsic factors. The principle factors that influence seed dormancy include certain PGRs and notably among them the abscisic acid (ABA) is involved in germination inhibition while gibberellins (GAs) participate in the termination of seed dormancy (Dewir et al., 2011; Halter et al., 2005). Commonly, PGRs improve seed germination capacity, increase biomass yield, and confer resistance to diseases and adverse growth conditions (Papadopoulos et al., 2006). GAs are generally synthesized by seeds and their role in germination is thought to be hydrolysis of storage nutrients in seeds and a direct effect on embryo growth (Lecat et al., 1992). External application of PGRs to seeds could break seed dormancy and enhance seedling establishment of many aromatic and medicinal plants (Ali et al., 2010; Gholami et al., 2013; Gupta, 2003; Kandari et al., 2008; Shivkumar et al., 2006; Zare et al., 2011).

In the present study, we investigated seed germination of three medicinal plant species viz. peppermint (*M. piperita* L. 'Black Mitcham'; Lamiaceae), sweet basil (*O. basilicum* L. 'Hamadany'; Lamiaceae), and coriander (*C. sativum* L. 'Sandra'; Apiaceae). Previous studies on seed germination of these plant species using PGRs are scarce. To our knowledge, Kumar et al. (2014) investigated seed germination of *C. sativum* using 2,4-dichlorophenozyacetic acid (2,4-D) and GA_3. The effect of different PGRs including 2,4-D, ethephon, GA_3, and NAA on seed germination of *Mentha arvensis* (*Mentha spicata* × *Mentha aquatic*) has been reported (Niu and Zhao, 2012); however, no reports were found on *M. piperita.* Therefore, we investigated presowing treatments with different PGRs including GA_3, IAA, IBA, and NAA at different concentrations with the aim to improve seed germination of these medicinally important plant species.

Materials and Methods

Seed collection and surface sterilization. Mature seeds of peppermint (*M. piperita* L. 'Black Mitcham'), sweet basil (*O. basilicum* 'Hamadany'), and coriander (*C. sativum* 'Sandra') were collected in Aug. 2014 from a private nursery, Riyadh, Saudi Arabia. The seeds were separated from the inflorescences, cleaned, and dried for a week at room temperature (25 ± 2 °C). The seeds were surface sterilized in 70% (v/v) ethanol for 1 min followed by 5% "v/v" sodium hypochlorite for 10 min and then washed with sterile distilled water before an experimental procedure to prevent contamination.

Seed germination procedure. The seeds were selected based on sinker and floater methods (Mandal, 2000) and those seeds that sink in water were used. The effects of four PGRs viz. GA_3, IAA, IBA, and NAA at 0, 50, 100, and 150 mg·L^{-1} concentrations were tested for seed germination of peppermint,

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sweet basil, and coriander in a controlled environment system. Seeds of uniform size were immersed in different concentrations of the four PGRs for 24 h and distilled water was used for control treatment. After the soaking treatment, 100 seeds were placed in a petri plate (90 × 15 mm) with double-layered wet Whatman No. 1 filter paper and the plates (three plates per treatment) were placed in a dark chamber at 23 ± 2 °C. Seed germination was checked daily for 20 d. Daily germination percentages were summed up to obtain cumulative germination percentage for each sowing treatment on each assessment date. A seed was considered germinated when the tip of the radicle had grown free of the seedcoat (Dewir et al., 2011). The germination parameters including FGP and CGRI were recorded according to Esechie (1994). A number of days lapsed to reach 50% of FGP were recorded according to Hsu et al. (1985).

Determination of phosphorus content in germinated seedlings. Phosphorus content in the germinated seeds of peppermint, sweet basil, and coriander was determined according to Page et al. (1982). On day 21 of germination, the germinated seedlings were oven-dried at 70 °C for 48 h. They were ground and homogenized in a solution of 8% trichloroacetic acid (w/v) in the presence of 2.0 g pure coarse sand. The resulted macerate was centrifuged at 5000 rpm for 5 min. Inorganic and organic phosphorous concentrations in the supernatant were determined colorimetrically at 710 nm using a Jenway 7300 spectrophotometer (Staffordshire, UK).

Determination of total protein content in germinated seedlings. On day 21 of germination, fresh germinated seedlings (0.5 g) of peppermint, sweet basil, and coriander were ground in a prechilled pestle, mortar in phosphate buffer saline containing NaCl (137 mM), KCl (2.7 mM), Na_2HPO_4 (2 mM), and cocktail protease inhibitors (1 mM). The pH was adjusted to 7.2 (Sambrook and Russell, 2001). The amount of total proteins was determined using a Bradford assay (Bradford, 1976).

Experimental design and statistical analysis. All experiments were conducted in a completely randomized design. There were 13 treatments replicated 3 times and each replication consisted of 100 seeds. Data were subjected to Duncan's multiple range test and least significant difference test using SAS Program (Version 6.12; SAS Institute Inc., Cary, NC).

Results and Discussion

Influences of PGRs on time-course changes of seed germination and germination parameters (FGP, CGRI, and GT_{50}) of peppermint, sweet basil, and coriander. Various presowing seed treatments with GA_3, IAA, IBA, and NAA improved the time-course changes in the germination percentage of peppermint (Fig. 1A–D), sweet basil (Fig. 1E–H), and coriander (Fig. 1I–L) as compared with control. PGRs concentrations also displayed variations in seed germination over the entire culture and were species dependent. The germination percentage for the control did not exceed 22.3%, 33.3%, and 27% for peppermint, sweet basil, and coriander, respectively. In general, GA_3 treatment was the most effective as compared with IAA, IBA, and NAA. GA_3 improved germination percentages by 52%, 32.6%, and 25.3% for peppermint, sweet basil, and coriander, respectively, as compared with control. However, germination percentages in IAA, IBA, and NAA treatments were also better than the control of the three plant species during the entire culture period. There were no considerable changes among IAA, IBA, and NAA treatments and control for the first 6 d for the three plant species. However, GA_3 tended to boost germination earlier as compared with different auxins for peppermint and sweet basil (Fig. 1A and E). The effects of various presowing treatments on FGP, CGRI, and GT_{50} percentages of peppermint, sweet basil, and coriander are presented in Table 1. GA_3 at 100 mg·L^{-1} significantly increased the FGP from 22.3% and 33.3% (control) to 74% and 65.6% for peppermint and sweet basil, respectively, while low concentration of GA_3 at 50 mg·L^{-1} increased the FGP for coriander from 27% to 52.3%. All other auxins treatments at different concentrations resulted in higher FGP than the control for the three plant species. IAA was more effective than IBA and NAA and showed stimulatory effects on seed germination. The germination speed (CGRI and GT_{50}) of the seeds as a result of PGRs treatments were significant for sweet basil and coriander but not for peppermint. The seeds reached 50% of their final germination in a minimum time (10.4 and 10.5 d) compared with control (12 and 12.1 d) for sweet basil and coriander, respectively. For peppermint, GT_{50} was delayed by 2–5 d depending on PGR treatment.

Plant seed germination is controlled by specific endogenous growth promoting and inhibiting compounds (Fang et al., 2006; Farhoudi et al., 2007; Hartmann et al., 1997) and there is a strong correlation among applied hormones, hormone concentration, specific developmental stage, and metabolic activities (Pedroza-Manrique et al., 2005). GA_3 is an

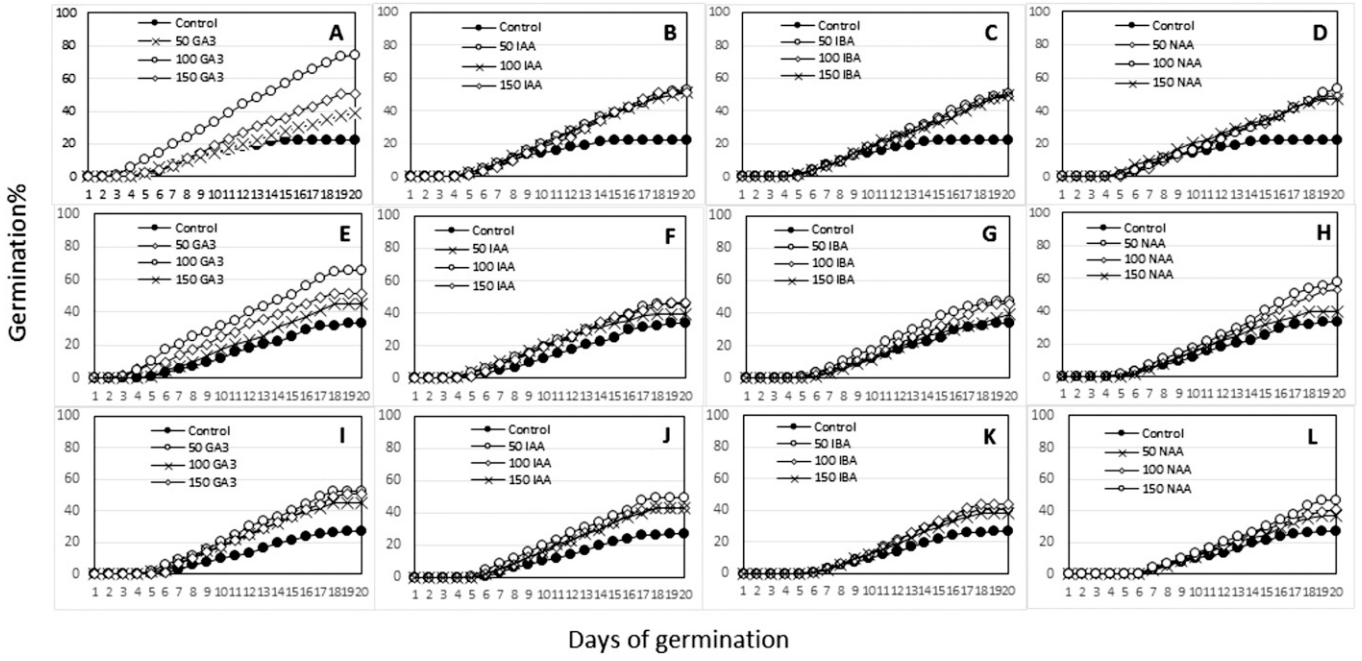

Fig. 1. Time-course changes in seed germination percentage of *Mentha piperita* (**A**–**D**), *Ocimum basilicum* (**E**–**H**) and *Coriandrum sativum* (**I**–**L**) as affected by presowing treatments with GA_3, IAA, IBA, and NAA (0, 50, 100, and 150 mg·L^{-1}) over 20 d of culture.

Table 1. Effect of presowing treatments on final germination percentage (FGP), corrected germination index (CGRI), and time taken to reach 50% of FGP (GT_{50}) for *Mentha piperita*, *Ocimum basilicum*, and *Coriandrum sativum* after 20 d in culture.

Treatment	Concn (mg·L^{-1})	FGP	CGRI	GT_{50}
		M. piperita		
Control	0	22.3 d[z]	89.4 a	9.3 b
GA_3	50	38.7 c	64.1 bcd	12.3 ab
	100	74.0 a	76.0 ab	15.0 a
	150	51.0 bc	61.9 bcd	14.0 a
IAA	50	53.0 b	62.8 bcd	12.3 ab
	100	51.0 bc	64.3 bcd	12.1 ab
	150	51.0 bc	60.9 bcd	12.3 ab
IBA	50	50.7 bc	61.9 bcd	12.6 ab
	100	49.0 bc	59.9 bcd	12.5 ab
	150	49.7 bc	58.9 cd	12.7 ab
NAA	50	49.0 bc	57.8 cd	12.7 ab
	100	53.3 b	54.7 d	13.2 ab
	150	47.3 bc	71.6 bc	11.4 ab
LSD		5.41	6.98	1.76
		O. basilicum		
Control	0	33.3 d	63.9 bc	12.0 abc
GA_3	50	51.0 bc	81.3 a	10.7 bc
	100	65.6 a	80.9 a	11.9 abc
	150	45.0 bcd	63.6 bc	12.6 ab
IAA	50	39.7 cd	80.6 a	10.4 c
	100	45.7 bcd	68.8 ab	11.6 abc
	150	46.3 bcd	67.8 abc	11.6 abc
IBA	50	47.0 bcd	65.7 bc	11.9 abc
	100	45.7 bcd	55.1 bc	12.9 a
	150	39.3 cd	56.6 bc	12.8 a
NAA	50	57.3 ab	56.7 bc	12.9 a
	100	53.3 abc	53.3 c	13.2 a
	150	39.3 cd	64.0 bc	11.9 abc
LSD		6.36	6.02	0.79
		C. sativum		
Control	0	27.0 e	62.0 abcd	12.1 bc
GA_3	50	52.3 a	65.7 a	11.8 bc
	100	45.0 abcd	66.0 a	11.5 c
	150	50.7 ab	59.1 abcde	13.9 a
IAA	50	49.7 abc	65.0 ab	11.8 bc
	100	42.7 abcd	61.9 abcd	12.1 bc
	150	42.7 abcd	63.5 abc	12.0 bc
IBA	50	40.3 bcd	64.5 ab	12.3 bc
	100	44.3 abcd	55.8 bcde	12.7 abc
	150	38.7 cd	57.8 abcde	12.5 abc
NAA	50	37.0 d	54.7 cde	12.9 abc
	100	41.0 abcd	53.6 de	13.1 ab
	150	47.0 abcd	52.2 e	13.3 ab
LSD		4.78	4.02	0.63

GA_3 = Gibberellic acid; IAA = indole-3-acetic acid; IBA = indol-3-butyric acid; NAA = naphthalene acetic acid; LSD = least significant difference.
[z]Mean separation within each column by Duncan's multiple range test at 5% level.

important endogenous growth regulator that involves the disappearance of ABA, mobilizes stored reserves, and weakens the mechanical resistance of the endosperm cells around the radicle tip (Gulzar et al., 2001). Also, GA_3 can eliminate the natural chilling requirement for dormant seeds (Fang et al., 2006). In general, application of GA_3 increased seed emergence percentage of many plant species including *Arbutus unedo* (Demirsoy et al., 2010), black gram and horse gram (Chauhan et al., 2009), and coriander (Kumar et al., 2014). However, the stimulatory effects of GA_3 on seed germination have been reported to be species/dose dependent. The seed germination rate of coriander increased by 19.13% as GA_3 concentration increased from 3.5 to 35 mg·L^{-1} (Kumar et al., 2014). GA_3 had deleterious effect on seed germination of *Oroxylum indicum* where the low concentration (17–35 mg·L^{-1}) reduced seed germination and the high concentration (52–70 mg·L^{-1}) produced abnormal seedlings (Singh et al., 2014). In the present study, GA_3 increased seed germination of peppermint, sweet basil, and coriander when applied at concentration of 50–100 mg·L^{-1}.

Several studies highlighted the promotive role of auxins on seed germination. It has been found that IAA was the most effective PGR for improving seed germination in *Allium victorialis* (Jeong et al., 2015). A promotive effect of IAA and IBA on seed germination of *Melia azedarach* was also reported (Banerji, 1998). NAA has been reported to increase seed germination of *Mentha arvensis* by 32.3% (Niu and Zhao, 2012). Different auxins (IAA, IBA, and NAA) improved seed germination of *Asparagus sprengeri* by 10% to 20% as compared with control. However, GA_3 was most effective in which seed germination increased by 47% (Dhoran and Gudadhe, 2012). IBA also has been reported to increase seed germination of *Jatropha curcas* by 52% when applied at 2.0 mg·L^{-1} (Kumari et al., 2010). However, IBA has been reported, in general, to be less effective than IAA and other PGRs for seed germination and it rather involved in seedling development. In the present study, application of IAA, IBA, and NAA increased seed germination of peppermint, sweet basil, and coriander depending on their concentrations. Among the tested PGRs in the present study, GA_3 was found to be highly effective to induce seed germination of peppermint, sweet basil, and coriander, as compared with IAA, IBA, and NAA. Among different auxins, IAA was better than IBA and NAA for seed germination of the three plants. These findings support previous reports in seed germination of *Vigna radiate* (Chakrabarti and Mukherji, 2003) and *Asparagus sprengri* (Dhoran and Gudadhe, 2012). The growth promoting effect of PGRs on seed germination in the present study could be attributed to their indirect effect such as change in the membrane permeability.

Influences of PGRs on phosphorus and protein contents of the germinated seedlings of peppermint, sweet basil, and coriander. The organic, inorganic, and total phosphorous in germinated seedlings of peppermint, sweet basil, and coriander were significantly increased by GA_3, IAA, IBA, and NAA treatments and their concentrations as compared with control (Table 2). Among different PGRs, GA_3 recorded the highest phosphorus content for peppermint (at 50 mg·L^{-1}) and sweet basil (at 50 or 100 mg·L^{-1}). For coriander, 100 mg·L^{-1} GA_3 recorded the highest inorganic as well as total phosphorus content while 50 mg·L^{-1} IAA recorded the highest organic phosphorus content. Among different auxins, IAA recorded higher phosphorus content in the germinated seedlings than IBA or NAA. These results indicate that GA_3 application affected the phosphate metabolism in peppermint, sweet basil, and coriander. Previous reports indicated that GA_3 may increase the level of the organic phosphates such as fructose 2, 6-bi-phosphate (Bewley and Black, 1994) and nucleotides (El-Dengawy, 1997). Moreover, El–Dengawy (1997) postulated that GA_3 treatment enhanced the incorporation of these nucleosides and nucleotides in nucleic acid synthesis that was needed for cell division of the embryo axis. Inorganic phosphate could progressively be released within the cotyledons during the degradation of phosphate-containing compounds while its reutilization by embryo axis is very slow (Bewley and Black, 1994).

Total protein contents in germinated seedlings of peppermint, sweet basil, and coriander were increased as a response of PGRs treatments and their concentrations (Table 2). GA_3 at 50 mg·L^{-1} resulted in a maximum amount of total protein in germinated seedlings [≈1.33 mg·g^{-1} fresh weight (FW)] of peppermint, sweet basil, and coriander as compared with control (≈0.66 mg·g^{-1} FW). Among different auxins,

Table 2. Effect of presowing treatments on phosphorus and proteins content in seedlings of *Mentha piperita*, *Ocimum basilicum*, and *Coriandrum sativum* after 20 d in culture.

Treatment	Concn ($mg \cdot L^{-1}$)	Organic phosphorous ($mg \cdot g^{-1}$ DW)	Inorganic phosphorous ($mg \cdot g^{-1}$ DW)	Total phosphorous ($mg \cdot g^{-1}$ DW)	Total proteins ($mg \cdot g^{-1}$ FW)
			M. piperita		
Control		0.84 j[z]	0.93 j	1.77 j	0.66 e
GA_3	50	1.68 a	1.66 a	3.43 a	1.33 a
	100	1.59 b	1.60 b	3.19 b	1.27 a
	150	1.49 cd	1.50 cd	2.99 c	1.22 ab
IAA	50	1.54 bc	1.46 de	3.00 c	1.12 b
	100	1.48 de	1.53 c	3.01 c	1.11 b
	150	1.37 f	1.42 e	2.78 d	1.11 b
IBA	50	1.44 e	1.34 f	2.77 d	0.92 c
	100	1.37 f	1.27 g	2.64 e	0.90 c
	150	1.28 g	1.21 h	2.49 g	0.86 c
NAA	50	1.27 g	1.29 fg	2.56 f	0.87 c
	100	1.20 h	1.21 h	2.41 h	0.77 d
	150	1.14 i	1.13 i	2.27 i	0.72 d
LSD		0.05	0.05	0.07	0.014
			O. basilicum		
Control		0.64 f	0.84 h	1.47 h	0.65 g
GA_3	50	1.47 a	1.54 a	3.01 a	1.33 a
	100	1.45 a	1.54 a	2.99 a	1.23 b
	150	1.43 a	1.40 cd	2.83 b	1.21 b
IAA g	50	1.43 a	1.42 c	2.85 b	1.11 c
	100	1.35 b	1.48 b	2.83 b	1.11 c
	150	1.24 c	1.38 d	2.62 b	1.10 c
IBA	50	1.33 b	1.26 e	2.59 c	0.91 d
	100	1.27 c	1.25 e	2.52 d	0.88 d
	150	1.26 c	1.15 f	2.41 e	0.84 d
NAA	50	1.16 d	1.26 e	2.42 e	0.85 d
	100	1.12 d	1.16 f	2.28 f	0.77 e
	150	1.05 e	1.05 g	2.10 g	0.71 f
LSD		0.07	0.03	0.07	0.009
			C. sativum		
Control		0.54 h	0.64 j	1.18 i	0.63 f
GA_3	50	1.26 b	1.33 c	2.59 b	1.32 a
	100	1.25 b	1.45 a	2.70 a	1.22 b
	150	1.22 c	1.28 d	2.50 c	1.20 b
IAA	50	1.36 a	1.24 e	2.60 b	1.11 c
	100	1.16 d	1.36 b	2.52 c	1.10 c
	150	1.14 d	1.25 e	2.93 d	1.10 c
IBA	50	1.24 bc	1.16 f	2.40 d	0.90 d
	100	1.15 d	1.15f g	2.30 e	0.87 d
	150	1.15 d	1.04 h	2.19 f	0.81 d
NAA	50	1.06 e	1.13 g	2.19 f	0.83 d
	100	1.04 f	1.06 h	2.10 g	0.76 e
	150	0.95 g	0.94 i	1.89 h	0.70 e
LSD		0.02	0.02	0.03	0.004

GA_3 = gibberellic acid; IAA = indole-3-acetic acid; IBA = indol-3-butyric acid; NAA = naphthalene acetic acid; LSD = least significant difference; DW = dry weight; FW = fresh weight.
[z]Mean separation within each column by Duncan's multiple range test at 5% level.

IAA recorded higher protein content in the germinated seedlings than IBA or NAA. It has been reported that the protein content of germinated *Lupinus angustifolius* seeds was increased by 38% after 9 d (Rumiyati and Jayasena, 2012). The increase in protein content after seed germination was also reported in other plant species such as *Trigonella foenumgraecum* (El-Mahdy and El-Sebaiy, 1982) and *Vicia faba* (Hsu et al., 1980) and *Phaseolus aureus* (Mubarak, 2005).

Our results demonstrate that presowing seed treatment with GA_3 is the most effective germination stimulant for seed germination of peppermint, sweet basil, and coriander indicating that the seeds possess physiological dormancy. Different auxins also showed a promotive effect on seed germination. IAA was better than IBA and NAA for seed germination. PGRs treatments increased total protein and phosphorus in germinated seedlings. The present study has established a successful methodology for overcoming seed dormancy and optimizing seed germination in peppermint, sweet basil, and coriander, to satisfy the demand for their medicinal parts in the pharmacological industry.

Literature Cited

Ali, T., P. Hossein, F. Asghar, Z. Salman, and Z.C.M. Ali. 2010. The effect of different treatments on improving seed germination characteristics in medicinal species of *Descurainia sophia* and *Plantago ovata*. Afr. J. Biotechnol. 9:6588–6593.

Banerji, U.K. 1998. Germination of *Melia azedarach* seed with IAA, IBA, and GA_3. Indian For. 124:220–222.

Bewley, J.D. and M. Black. 1994. Seeds: Physiology of development and germination. Plenum Press, New York.

Bradford, M.M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of dye binding. Ann. Biochem. 72:247–254.

Chakrabarti, N. and S. Mukherji. 2003. Effect of phytohormone pre-treatment on nitrogen metabolism in *Vigna radiate* under salt stress. Biol. Plant. 46:63–66.

Chauhan, J.S., Y.K. Tomar, N.I. Singh, S. Ali, and Debarati. 2009. Effect of Hormones on seed germination and seedling growth of black and horse gram. J. Amer. Sci. 5:79–84.

Copeland, L.O. and M.B. McDonald. 2001. Principles of seed science and technology. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Demirsoy, L., H. Demirsoy, G. Celikel, I. Macit, and B. Ersoy. 2010. Seed treatment with GA_3 or stratification enhances emergence of some strawberry tree genotypes. Hort. Sci. 37:34–37.

Dewir, Y.H., M.E. El-Mahrouk, and Y. Naidoo. 2011. Effects of some mechanical and chemical treatments on seed germination of *Sabal palmetto* and *Thrinax morrisii* palms. Austral. J. Crop Sci. 5:245–250.

Dhoran, V.S. and S.P. Gudadhe. 2012. Effect of plant growth regulators on seed germination and seedling vigour in *Asparagus sprengeri* Regelin. Intl. Res. J. Biol. Sci. 1:6–10.

El-Dengawy, R.F.A. 1997. Physiological and biochemical studies on seeds dormancy and germination process in deciduous fruit trees. Fac. Agr. Mansoura Univ., Egypt.

El-Mahdy, A. and L. El-Sebaiy. 1982. Effect of germination on the nitrogenous constituents, protein fractions, *in vitro* digestibility and antinutritional factors of fenugreek seeds (*Trigonella foenumgraecum* L.). Food Chem. 8:253–262.

Esechie, H. 1994. Interaction of salinity and temperature on the germination of sorghum. J. Agron. Crop Sci. 172:194–199.

Fang, S., J. Wang, Z. Wei, and Z. Zhu. 2006. Methods to break seed dormancy in *Cyclocarya paliurus* (Batal) Iljinskaja. Sci. Hort. 110:305–309.

Farhoudi, R., M.T. Makkizadeh, F. Sharifzadeh, M. Kochak-Por, and S. Rashidi. 2007. Study of dormancy-breaking of Madder seed (*Rubia tinctorum*). Seed Sci. Technol. 35:739–743.

Finch-Savage, W.E. 1995. Influence of seed quality on crop establishment, growth and yield, p. 470. In: A.S. Basra (ed.). Seed quality: Basic mechanisms and agricultural implications. Food Products Press, Binghamton, NY.

Gholami, H., R. Farhadi, M. Rahimi, A. Zeinalikharaji, and A. Askari. 2013. Effect of growth hormones on physiology characteristics and essential oil of basil under drought stress condition. J. Amer. Sci. 9:61–63.

Gulzar, S., M.A. Khan, and I.A. Ungar. 2001. Effect of salinity and temperature on the germination of *Urochonra setulosa* Hubbard. Seed Sci. Technol. 29:21–29.

Gupta, V. 2003. Seed germination and dormancy breaking techniques for indigenous medicinal and aromatic plants. J. Med. Aromatic Plants Sci. 25:402–407.

Halter, L., R. Habegger, and W.H. Schnitzler. 2005. Gibberellic acid on artichokes (*Cynara scolymus* L.) cultivated in Germany to promote earliness and to increase productivity. Acta Hort. 681:75–82.

Hartmann, H.T., D.E. Kester, F.T. Davies, and R.E. Geneve. 1997. Plant propagation—principles and practices. 6th ed. Prentice-Hall Inc., Upper Saddle River, NJ.

Hassan, B.A.R. 2012. Medicinal plants (importance and uses). Pharm. Anal. Acta 3:139.
Hidayati, S.N., J.L. Walck, D.J. Merritt, S.R. Turner, and D.W. Turner. 2012. Sympatric species of Hibbertia (Dilleniaceae) vary in dormancy break and germination requirements: Implications for classifying morphophysiological dormancy in Mediterranean biomes. Ann. Bot. 109:1111–1123.
Hsu, D., H. Leung, P. Finney, and M. Morad. 1980. Effect of germination on nutritive value and baking properties of dry peas, lentils, and faba beans. J. Food Sci. 45:87–92.
Hsu, F.H., C.J. Nelson, and A.G. Matches. 1985. Temperature effects on germination of perennial warm-season forage grasses. Crop Sci. 25:212–220.
Jeong, M.J., H.J. Song, S.J. Sim, Y.R. Seo, H.J. Im, G.U. Suh, C.S. Karigar, and M.S. Choi. 2015. Enhancement of seed germination and seedling growth of *Allium victorialis* var. *platyphyllum* by the soaking treatment of plant growth regulators. J. Agr. Life Sci. 49:51–62.
Kandari, L.S., K.S. Rao, R.K. Maikhuri, and K. Chauhan. 2008. Effect of pre-sowing, temperature and light on the seed germination of Arnebia benthamii (Wall. ex G. Don): An endangered medicinal plant of Central Himalaya, India. Afr. J. Plant Sci. 2:005–011.
Kumar, M., R.K. Agnihotri, R. Vamil, and R. Sharma. 2014. Effect of phytohormones on seed germination and seedling growth of *Coriandrum sativum* L. Pak. J. Biol. Sci. 17:594–596.
Kumari, M., V.Y. Patade, M. Arif, and Z. Ahmed. 2010. Effect of IBA on seed germination, sprouting and rooting in cuttings for mass propagation of *Jatropha curcas* L. strain DARL-2. Res. J. Agr. Biol. Sci. 6:691–696.
Lecat, S., F. Corbineau, and D. Còme. 1992. Effects of gibberellic acid on the germination of dormant oat (*Avena sativa* L.) seeds as related to temperature, oxygen and energy metabolism. Seed Sci. Technol. 20:421–433.
Macchia, M., L.G. Angelini, and L. Ceccarini. 2001. Methods to overcome seed dormancy in *Echinacea angustifolia* DC. Sci. Hort. 89:317–324.
Mandal, R.C. 2000. Cashew production and processing technology. Agrobios Publishers, Ludhiana, India.
Mubarak, A.E. 2005. Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. Food Chem. 89:489–495.
Niu, W.H. and Y. Zhao. 2012. Effects of different hormone pretreatments on the germination of *Mentha arvensis* (Peppermint) seeds. Med. Plant 3:64–66.
Page, A.L., R.H. Miller, and D.R. Kenney. 1982. Methods of soil analysis, Part II. American Society of Agronomy, Madison, WI.
Papadopoulos, A.P., U. Saha, X. Hao, and S. Khosla. 2006. Response of rockwool-grown greenhouse cucumber, tomato, and pepper to kinetin foliar sprays. HortTechnology 16:32–35.
Pedroza-Manrique, J., C. Fernandez-Lizarazo, and A. Suarez-Silva. 2005. Evaluation of the effect of three growth regulators in the germination of *Comparettia falcata* seeds under *in vitro* conditions. In Vitro Cell. Dev. Biol. Plant 41:838–843.
Pereira, T.S. 1992. Seed germination of *Bauhinia forficata* Link. (Leguminosae-Caesalpinoideae). J. Seeds 14:77–82.
Rumiyati, A.P.J. and V. Jayasena. 2012. Effect of germination on the nutritional and protein profile of Australian sweet lupin (*Lupinus angustifolius* L.). Food Nutr. Sci. 3:621–626.
Sajjadi, S.E. 2006. Analysis of the essential oils of two cultivated basil (*Ocimum basilicum* L.) from Iran. Daru 14:128–130.
Sambrook, J. and D.W. Russell. 2001. Molecular cloning—a laboratory manual. 3rd ed. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY.
Shivkumar, V., R. Anandlakshmi, R.R. Warrier, M. Tigabu, P.C. Oden, S.N. Vijayachandran, S. Geetha, and B.G. Singh. 2006. Effect of presowing treatments, desiccation and storage conditions on germination of *Strychnos nux-vomica* seeds, a valuable medicinal plant. New For. 32:121–131.
Singh, M., K.K. Singh, and H.K. Badola. 2014. Effect of temperature and plant growth regulators on seed germination response of *Oroxylum indicum*—a high value threatened medicinal plant of Sikkim Himalaya. J. Plant Sci. Res. 1:115.
Zare, A.R., M. Solouki, M. Omidi, N. Irvani, A.O. Abasabadi, and N.M. Nezad. 2011. Effect of various treatments on seed germination and dormancy breaking in *Ferula assafoetida* L. (Asafetida), a threatened medicinal herb. Trakia J. Sci. 9:57–61.