The Future of Horticulture

FSA

Article

Plant Growth, Productivity and Chemical Components of *Echinacea purpurea* L. Plant as Affected by Cultivation Method and Pinching

Walid M.A. Moghith

Medicinal and Aromatic Plants Department, Desert Research Center, Cairo, Egypt.

***Corresponding author:** walidmoghith@drc.gov.eg

Abstract: The study was conducted at the Experimental Station of the Desert Research Center in Ras Sudr, South Sinai Governorate, Egypt, during the two seasons of 2021 and 2022. This study aimed to investigate the effects of two cultivation methods (direct seeding and transplanting) and different pinching treatments (control, single pinching, and double pinching) on vegetative and flowering characters (plant height, branches number/plant, fresh weight of herb/plant and dry weight of herb/plant, number of flowering heads/plant, fresh weight of flowering heads/plant and dry weight of flowering heads/plant) and chemical components (N, P, K, leaf chlorophyll content (SPAD unit) and carbohydrate percentage) of *Echinacea purpurea* L. plants. The findings demonstrated the effects of cultivation methods and pinching on *Echinacea purpurea* L.; in most cases, transplanting is a better cultivation method than direct seeding, particularly when it comes to the characteristics of the plant's fresh and dry weight, which in turn influences the plant's fresh and dry yield, which is the economically significant portion of *Echinacea purpurea*; for vegetative traits, single pinching was the best pest treatment; on the other hand, for the number and weight of flowering head characters, double pinching was the most effective strategy; nevertheless, there are some minor nutrient deficiencies in the plant content that should be noted.

Key words: *Echinacea purpurea* L., pinching, transplanting, flowering heads.

Future Science Association

Available online free at
www.futurejournals.org

Print ISSN: 2692-5826

Online ISSN: 2692-5834

DOI:
10.37229/fsa.fjh.2023.09.29

Received: 20 July 2023
Accepted: 15 September 2023
Published: 29 September 2023

1. Introduction

Medicinal plants occupy great importance in the agricultural list of various countries due to their economic and medical importance at the same time **(Mohammed, 2019).** *Echinacea purpurea* (L.) Moench, commonly known as the purple coneflower, is a flowering plant belonging to the family Asteraceae **(Foster, 1991).** It is native to North America, where it thrives in prairies and open woodlands. The species is characterized by its vibrant purple petals and a central cone composed of disk florets. The genus *Echinacea* is composed of several species, with *Echinacea purpurea* being one of the most widely recognized due to its medicinal properties and ornamental appeal. The roots, flowers, and leaves were commonly used in teas and poultices to alleviate symptoms associated with cold and flu (**Foster, 1991; Melchart *et al.*, 1994 and Seckin *et al.*, 2018).** The therapeutic properties of *Echinacea purpurea* are attributed to its diverse array of phytochemicals. The major constituents include phenolic compounds such as cichoric acid, caftaric acid, and echinacoside, which exhibit antioxidant and anti-inflammatory activities. Additionally, *Echinacea purpurea* contains alkamides, glycoproteins, and polysaccharides, all of which contribute to its immunomodulatory effects. Alkamides are particularly noted for their role in enhancing immune response by modulating the activity of macrophages and cytokine production. These bioactive compounds collectively make *E. purpurea* a popular natural remedy for boosting the immune system and reducing symptoms of respiratory infections (**Bauer, 1999; Hudson, 2012; Burlou-Nagy *et al.*, 2022 and Vasiu *et al.*, 2023).** The economic significance of *Echinacea purpurea* has grown substantially over the past few decades, driven by the increasing demand for herbal supplements and natural remedies. The global market for Echinacea products, including extracts, capsules, and teas, is robust, with North America and Europe being the largest consumers. The popularity of Echinacea in the wellness industry underscores its economic value, with ongoing research and development further expanding its market potential (**Zheng *et al.*, 2006 and Najm and Lie, 2008).**

Given the economic and medicinal importance of this plant, optimizing cultivation techniques such as direct seeding and transplanting is crucial for maximizing yield. Direct seeding, in contrast, involves planting seeds directly into the soil where they will grow to maturity. This method is less labor-intensive than transplanting and can be more cost-effective, especially for large-scale operations. Direct seeding is often used for medicinal and aromatic plants that are hardy and capable of germinating and growing under a wide range of environmental conditions **(Falk *et al.*, 2000).** However, one of the challenges with direct seeding is the potential for uneven germination and plant density, which can lead to variability in crop yield and quality. Despite this, direct seeding remains a popular method for fast-growing plants or those cultivated on a large scale due to its simplicity and lower costs **(Malhotra, 2016).** Transplanting involves starting seeds in a controlled environment like a greenhouse or nursery before transferring the seedlings to the field. Several crops have shown that transplanting is a dependable way to get early maturity and increase yield. This method is particularly advantageous for medicinal and aromatic plants that have delicate seedlings or require specific conditions for germination (**Ketema *et al.*, 2013 and Leskovar and Othman, 2021).** By controlling the early stages of growth, transplanting helps ensure uniformity in plant size and health, which can lead to better overall crop performance. Moreover, this method can extend the growing season by allowing plants to be started earlier than they could be directly seeded in the field. Studies have shown that transplanting is often preferred for high-value crops where maximizing yield and quality is essential (**William *et al.*, 1992 & Finch-Savage and Bassel, 2016**). For instance, transplanting is commonly used in the cultivation of species like *Ocimum basilicum* (basil), which benefits from the controlled conditions during its early growth stages **(Srivastava *et al.*, 2018)**. The choice between transplanting and direct seeding for medicinal and aromatic plants is influenced by several factors, including the specific plant species, local environmental conditions, and the economic goals of the cultivation. **Falk *et al.* (2000)** on some medicinal herbs indicted that the transplanting resulted in a higher return to land and risk. **Behera *et al.* (2020)** on *Hedychium coronarium* (butterfly ginger) has shown that the propagation method can significantly affect plant health and yield. In this study, synthetic seeds were developed as a viable alternative to both direct seeding and traditional transplanting, demonstrating the ongoing innovations in the field of medicinal and aromatic plants cultivation**. Singh *et al.* (2019a)** on Indian mustard revealed that using transplanting techniques instead of direct crop seeding enhanced the seed yield by 15% to 20%.

Pinching is a horticultural technique that involves the removal of the growing tip of a plant to encourage lateral branching. In pinching the apical meristem is removed, forcing the plant to grow two or more new stems from the nodes below the pinch (**Cheema, 2018).** Pinching is one such method that enables side branches to grow by removing some leaves and the apical buds **(Rajput *et al.*, 2020).** Pinching has several advantages, such as lateral bud development stimulation, enhanced fruit production and disease prevention **(Jyothi *et al.*, 2018).** Pinching may increase yield by promoting the establishment of several terminal branches that produce blooms **(George, 2004).** The selection of the appropriate method is crucial for ensuring that medicinal and aromatic plants cultivation contributes to both economic development and environmental sustainability **(Ur-Rahman and Sher, 2019).** The current study aimed to evaluate the effect of cultivation method and pinching on plant growth, productivity and chemical components of the *Echinacea purpurea* L. plant.

2. Material and Methods

2.1. Site description, plant materials, experimental layout and treatments

At the Experimental Station of Desert Research Center in Ras Sudr, South Sinai Governorate, Egypt (29°37'28.0"N 32°42'46.0"E), we conducted field experiment during the growing summer seasons of 2021 and 2022 to investigate the effect of two cultivation method, and pinching on the growth and chemical constituents of *Echinacea purpurea* L. plants. The seeds were collected from mature *Echinacea purpurea* L. plants grown on a private farm in the Qaliubiya Governate, Egypt. After being sown in seedling trays, the seeds were lightly covered and kept in a plastic greenhouse until they germinated. On the second week of March each season, *Echinacea purpurea* L. seedlings (8-10 cm height) were transplanted into the open field with a 20 cm space between plants and a 50 cm between rows for transplanting treatments, while the direct seeding treatments, the seed were sowing in the soil experiment directly at the same time as transplanting seedlings. All recommended cultural procedures for cultivating *Echinacea purpurea* L. plants were adhered to, as advised in this Egypt, and the plants were directly irrigated with water at 2300 ppm using a drip irrigation system to supply the right amount of moisture for growth. The plants were cut twice: on July 10th and October 23rd for the first season and on July 15th and October 20th for the second season, respectively.

The soil of the location was a sandy loam texture, pH 7.4, EC 4.65 mS cm^{-1}, and $CaCO_3$ 54.21 %. Physical and chemical analyses of the soil were determined according to **(Burt, 2004).** The layout of this experiment was a factorial experiment in a split-plot arrangement, incorporating two factors and six treatments. These treatments were combinations of two cultivation methods (direct seeding and transplanting) and three pinching treatments [without pinching as a control, single pinching (30 days), and double pinching (30 and 45 days) after transplanting for the direct seeding and transplanting treatments]. The design featured three replications, with the main plots assigned to the cultivation methods and the sub-plots designated for the pinching treatments.

2.2. Vegetative growth characters

At the beginning of flowering, the vegetative growth traits (plant height, branches number/plant, fresh weight of herb/plant and dry weight of herb/plant) were measured.

2.3. Number and weight of flowering heads

Number of flowering heads/plant, fresh weight of flowering heads/plant and dry weight of flowering heads/plant were recorded at flowering stage.

2.4. Chemical components

Total carbohydrate percentages in the dried leaves at the flowering stage were determined according to **(Chaplin and Kennedy. 1994)**. N, P and K were determined according to **A.O.A.C. (1970), Murphy and Riley (1962), Cottenie *et al.* (1982),** respectively. SPAD-meter measurements Opti-science CCM-200 meter (USA) was used for assessment of leaf chlorophyll content (**Dong *et al.*, 2019).**

2.5. Statistical analysis

The means of all obtained data as an average of the two cuts from the studied factors were subjected to analyses of variance (ANOVA). For means' comparison, the L.S.D. test was used to compare means at the 0.05% level using the MSTAT-C statistical software package according to **(Snedecor and Cochran, 1989).**

3. Results and Discussion

3.1. Vegetative growth characters

Results revealed that the *Echinacea purpurea* vegetative growth parameters were significantly affected by the transplanting method and pinching (Table 1). In both seasons, the transplanting method significantly increased the number of branches per plant and the fresh and dry weight of the herb per plant, highlighting its effectiveness in maximizing biomass production. The taller plants resulted from the direct seeding method. Concerning pinching, it significantly affected all growth parameters in both seasons. The most effective treatment for enhancing the number of branches and fresh and dry weight of the herb was the double pinching, which accepts the height value of plant height that resulted from the single pinching treatment. The interaction between transplanting and double-pinching was particularly noteworthy. This combination produced the highest number of branches and the greatest biomass. The results suggest that transplanting coupled with double pinching optimizes both vegetative growth and yield in *Echinacea purpurea,* making it the most effective strategy for cultivation. However, the tallest plants were obtained from the interaction between transplanting and single pinching treatment. The differences among treatments were significant in both seasons.

Table (1). Effect of cultivation method and pinching treatments on plant height, number of branches/plant, fresh weight of herb/plant and dry weight of herb/plant of *Echinacea purpurea* L. plant as an average of the two cuts during 2021 and 2022 seasons

	First season (2021)				Second season (2022)			
Treatments	Control	SP	DP	Mean	Control	SP	DP	Mean
	Plant height (cm)							
DS	71.67	63.93	56.70	64.10	73.03	64.57	58.13	65.24
TP	74.67	66.53	58.87	66.69	75.73	67.17	60.27	67.72
Mean	73.17	65.23	57.78		74.38	65.87	59.20	
L.S.D.	CM=2.63		P=1.84	CM×P=2.60	CM=2.57		P=2.60	CM×P=3.67
	Number of branches							
DS	12.33	16.33	19.00	15.89	13.33	16.67	20.33	16.78
TP	14.00	18.33	21.00	17.78	14.67	19.00	20.67	18.11
Mean	13.17	17.33	20.00		13.33	16.67	20.33	
L.S.D.	CM=1.27		P=1.55	CM×P=2.20	CM=1.43		P=1.60	CM×P=2.26
	Fresh weight of herb/plant (g)							
DS	192.4	206.3	214.2	204.3	193.5	205.0	215.8	204.8
TP	196.7	209.9	219.6	208.7	197.5	211.2	221.8	210.2
Mean	194.5	208.1	216.9		195.5	208.1	218.8	
L.S.D.	CM=7.81		P=8.43	CM×P=11.92	CM=5.29		P=7.24	CM×P=10.24
	Dry weight of herb/plant (g)							
DS	34.53	36.40	37.97	36.30	35.03	37.17	38.60	36.93
TP	36.43	38.20	38.90	37.84	37.10	39.05	40.19	38.78
Mean	35.48	37.30	38.43		36.07	38.11	39.39	
L.S.D.	CM=2.68		P=2.00	CM×P=2.83	CM=3.71		P=1.53	CM×P=2.17

DS: Direct seeding, TP: Transplanting, P: Pinching, SP: Single pinching, DP: Double Pinching, CM: Cultivation method

3.2. Number and weight of flowering heads

Data in Table 2 revealed that the transplanting method resulted in a higher number of flowering heads per plant and a heavier fresh and dry weight of flowering heads per plant compared to the direct seeding method in both seasons. Pinching treatments, particularly double pinching, significantly increased the number of flowering heads and their fresh and dry weights per plant compared with single pinching. Regarding the interaction between cultivation method and pinching, the treatment of transplanting method and double pinching produced the most favorable results, with the highest number and weight of flowering heads per plant as an average of the two cuts during both seasons. This combination appears to enhance the reproductive capacity of *Echinacea purpurea*, making it the optimal approach for achieving maximum floral production.

Table (2). Effect of cultivation method and pinching on number of flowering heads/plant, fresh weight of flowering heads/plant and dry weight of flowering heads/plant of *Echinacea purpurea* L. plant as an average of the two cuts during 2021 and 2022 seasons

	First season (2021)				Second season (2022)			
Treatments	Control	SP	DP	Mean	Control	SP	DP	Mean
	Number of flowering heads/plant							
DS	17.67	23.00	28.00	22.89	18.33	23.67	29.00	23.67
TP	19.00	25.33	30.67	25.00	20.00	24.67	29.67	24.78
Mean	18.33	24.17	29.33		19.17	24.17	29.33	
L.S.D.	CM=2.66	P=1.60	CM×P=2.22		CM=4.56	P=1.83	CM×P=2.59	
	Fresh weight of flowering heads/plant (g)							
DS	87.33	90.33	93.40	90.36	88.53	91.13	94.30	91.32
TP	86.28	94.80	96.91	92.67	87.97	94.13	94.97	92.36
Mean	86.81	92.57	95.16		88.25	92.63	94.63	
L.S.D.	CM=3.54	P=2.81	CM×P=3.97		CM=4.38	P=2.97	CM×P=4.21	
	Dry weight of flowering heads/plant (g)							
DS	15.65	16.50	18.46	16.87	15.15	16.15	1810	16.47
TP	16.75	19.38	20.47	18.87	16.40	18.82	19.95	18.39
Mean	16.20	17.94	19.46		15.77	17.49	19.02	
L.S.D.	CM=1.25	P=0.75	CM×P=1.06		CM=1.88	P=0.91	CM×P=1.29	

DS: Direct seeding, TP: Transplanting, P: Pinching, SP: Single pinching, DP: Double Pinching, CM: Cultivation method

The results of this study demonstrate significant effects of cultivation methods and pinching treatments on the growth, yield, and quality of *Echinacea purpurea*, consistent with findings in similar plant species. This resulted in the same trend as **Falk *et al.* (2000)** who stated that *Nepeta cataria* L., *Urtica dioica* L., *Calendula officinalis* L., *Melissa officinalis* L., and *Sphaeralcea incana* were significantly affected by transplanting and direct seeding, transplanting was outperformed on direct seeding, as shown by **Ketema *et al.* (2013)** on onion, **Bahlgerdi *et al.* (2014)** on medicinal pumpkin, **Susila and Reddy (2017)** on *Psoralea corylifolia*, **singh *et al.* (2019a)** on Indian mustard, **Gavrić and Omerbegović (2020)** on sweet corn, **Lee *et al.* (2021)** on *Brassica napus*, **Leskovar and Othman (2021)** on Globe Artichoke, **Rahman *et al.* (2022) and Mansouri *et al.* (2023)** on Quinoa. Pinching, particularly double pinching, was observed to increase branching and floral production while reducing plant height. This aligns with the work of **AbouDahab *et al.* (2013)** on *Cestrum nocturnum* who found pinching the plants once decreased the fresh weight of branches, twice pinching the plants resulted in an increase in the number of branches, stem and branch diameter, fresh and dry weights of the shoots, and reduced branch length and dry weight. The results indicated that pinching recorded the significant increase in vegetative growth (plant height, branch number/plant, fresh and dry weights of herb/plant, leaf number and leaf area/plant), and flowers traits (flower number/plant and flowers fresh and dry weights per plant and feddan) compared to other pinching treatments on marigold plants **(Ibrahim, 2017).** The outcomes of many experiments revealed that the double pinching treatment had the highest plant spread, the greatest number of branches, the longest flowering period, the number of flowers per plant, the size and weight of each flower, the flower yield per plant, and the seed production per plant, while double pinching was maximum flower yield production, yielding three times more than the control **Singh *et al.* (2019b), Kumar *et al.* (2020)** discovered that the effects of pinching treatments had a noteworthy effect on plant height, the number of branches, nodes, stem diameter, plant spread, the number of flowers, flower diameter, number of buds, fresh and dry flower weights, flower yield/plant, flower yield/plot, and flower yield/hectare. **Ehsanullah *et al.* (2021)** on *Chrysanthemum indicum* found that the pinching treatments enhanced the branch number, leaf number, plant spread, and flower size, but the plant height was decreased. **Jena *et al.* (2021)** on *Chrysanthemum coronarium* found that parameters like number of leaves and primary ranches, number of flowers per plant, number of flowers per plot, as well as per hectare were observed to be maximum under this double pinching treatment. **Badge and Ganvir (2022)** on African marigold found that plants pinched between 30 days after transplanting were found best for better growth, flowering, and yield of marigold. The investigation conducted by **Chandio *et al.* (2023)** on marigold revealed a noteworthy impact of the pinching treatments on plant height, flower diameter, number of leaves/plant, fresh biomass of flower, number of flowers per plant, and number of branches/plant, all of which were noted.

3.3. Chemical components

Data in Table 3 showed that the transplanting method significantly influenced the plant content of potassium and carbohydrates percentage in the plants compared to the direct seeding method, while the same treatment had a non-significant effect on N, P and leaf chlorophyll content in both seasons. In general, pinching, especially single pinching significantly reduced the plant content of N, P, k, carbohydrates and leaf chlorophyll content in both seasons. The interaction between the transplanting method and double pinching showed a nuanced impact on nutrient content. All treatments slightly decreased the nutrient percentages (N, P and K), carbohydrate, and leaf chlorophyll content compared to control plants in both seasons.

Table (3). Effect of cultivation method and pinching on chemical components of *Echinacea purpurea* L. plant as an average of the two cuts during 2021 and 2022 seasons

	First season (2021)				Second season (2022)			
Treatments	Control	SP	DP	Mean	Control	SP	DP	Mean
	N %							
DS	2.26	2.14	1.95	2.11	2.40	2.29	2.03	2.24
TP	2.11	2.03	1.96	2.04	2.22	2.13	1.99	2.11
Mean	2.18	2.09	1.96		2.31	2.21	2.01	
L.S.D.	CM=0.59		P=0.19	CM×P=0.27	CM=0.43		P=0.22	CM×P=0.32
	P %							
DS	0.917	0.857	0.793	0.856	0.943	0.880	0.813	0.879
TP	0.887	0.813	0.776	0.828	0.910	0.853	0.807	0.857
Mean	0.902	0.839	0.785		0.927	0.867	0.810	
L.S.D.	CM=0.111		P=0.073	CM×P=0.103	CM=0.091		P=0.060	CM×P=0.084
	K %							
DS	1.76	1.72	1.63	1.70	1.79	1.70	1.66	1.72
TP	1.74	1.68	1.63	1.68	1.77	1.71	1.65	1.71
Mean	1.75	1.70	1.63		1.78	1.71	1.65	
L.S.D.	CM=0.002		P=0.07	CM×P=0.10	CM=0.002		P=0.06	CM×P=0.08
	Leaf chlorophyll (SPAD unit)							
DS	61.33	53.00	48.63	54.32	62.17	54.78	49.23	55.39
TP	60.53	50.13	44.67	51.78	61.70	51.77	45.33	52.39
Mean	60.93	51.57	46.65		61.93	53.28	47.28	
L.S.D.	CM=10.48		P=5.45	CM×P=7.71	CM=7.43		P=5.60	CM×P=7.91
	Carbohydrate %							
DS	24.82	22.73	21.10	22.88	25.13	23.43	21.95	23.50
TP	23.90	22.78	20.67	22.45	24.24	23.03	21.97	23.08
Mean	24.36	22.76	20.88		24.69	23.23	21.96	

DS: Direct seeding, TP: Transplanting, P: Pinching, SP: Single pinching, DP: Double Pinching, CM: Cultivation method

Similarly, **Lee *et al.* (2021)** indicted that transplanting and direct seeding had no effect on oil content and oil composition between the two cultivation methods in most cases, and **Bahlgerdi *et al.* (2014)** on medicinal pumpkin stated that the oil content was not affected by cultivation methods. In addition, the results of pinching treatments were in a similar direction with **AbouDahab *et al.* (2013)** on *Cestrum nocturnum* who found that pinching the plants (once and twice) decreased N, P, k, chlorophyll a, chlorophyll b, and carotenoids in the shoots, and **Sathappan (2018)** who stated that pinching had a non-significant effect on the xanthophyll content of *Tagetes erecta* L. Pinching recorded the significant increase in chemical constituents, i.e., N, P, K percentages, chlorophyll a, chlorophyll b content and petals carotenoids contents compared to other pinching treatments on marigold plants **Ibrahim (2017) and Halagi *et al.* (2023)** on *Tagetes erecta* L., who showed that pinching increased chlorophyll in plants compared with control.

4. Conclusion

The results showed the effects of cultivation method, pinching, and their interaction on *Echinacea purpurea* L.; the transplanting as a cultivation method is superior to direct seeding in most cases, especially the characteristics of the fresh and dry weight of the plant, which in turn affects the fresh and dry crop of the plant, which is the economic part of *Echinacea purpurea*. Single pinching was the pest treatment for vegetative traits, while double pinching was the best for the number and weight of flowering heads characters. Transplanting, combined with single pinching, appears to be the most effective strategy, while noting some minor deficiency in the plant content of some nutrients.

References

AbouDahab, T.M.; Habib, A.M. and Mousa, G.M. (2013). Effect of paclobutrazol and pinching on *Cestrum nocturnum* plants. Annals of Agricultural Science, Moshtohor, 51(1): 23-34.

A.O.A.C. (1970). Official Methods of Analyses, 10th ed. Association of Official Agriculture Chemists. Washington, D.C., U.S.A.

Badge, S. and Ganvir, G.B. (2022). Growth and flower production as influenced by pinching in African marigold: A review. Annals of Plant Sciences, 11(1): 4527-4536.

Bahlgerdi, M.; Aroiee, H. and Azizi, M. (2014). The study of plant density and planting methods on some growth characteristics, seed and oil yield of medicinal pumpkin (*Cucurbita pepo* Var. Styriaca, Cv. ‘Kaki). American Journal of Life Sciences, 2(5): 319-324. https://doi.10.11648/j.ajls.20140205.21.

Bauer, R. (1999). Chemistry, Analysis and Immunological Investigations of Echinacea Phytopharmaceuticals. In: Wagner, H., Ed., Immunomodulatory Agents from Plants, Birkhäuser Basel, Basel, 41-88. https://doi.org/10.1007/978-3-0348-8763-2_2.

Behera, S.; Rout, K.K.; Panda, P.C. and Naik, S.K. (2020). Production of non-embryogenic synthetic seeds for propagation and germplasm transfer of *Hedychium coronarium* J. Koenig. Journal of Applied Research on Medicinal and Aromatic Plants, 19: 100271. https://doi.org/10.1016/j.jarmap.2020.100271.

Burlou-Nagy, C.; Bănică, F.; Jurca, T.; Vicaș, L.G.; Marian, E.; Muresan, M.E.; Bácskay, I.; Kiss, R.; Fehér, P. and Pallag, A. (2022). *Echinacea purpurea* (L.) Moench: Biological and Pharmacological Properties. A Review. Plants (Basel), 11(9):1244.

Burt, R. (2004). Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42, version 4.0. USDA-NRCS, Lincoln, p 700.

Chandio, S.R.; Meghwar, M.R.; Shar, A.B.; Wagan, M.A. and Shar, I.A. (2023). Effect of pinching on growth and yield of marigold. Big Data in Agriculture (BDA), 5(2): 53-56. http://doi.org/10.26480/bda.02.2023.53.56.

Chaplin, M.F. and Kennedy, J.F. (1994). Carbohydrate Analysis, 2nd ed. Oxford University Press, New York.

Cheema, B.I. (2018). Effect of pinching and spacing on the growth and development of sunflowers (*Helianthus annuus*) in East Texas. M.Sc. Faculty of the Graduate School of Stephen F. Austin State University. pp. 7-8.

Cottenie, A.; Verloo, M.; Velghe, M. and Camerlynck, R. (1982). Chemical Analysis of Plant and Soil. Laboratory of Analytical and Agrochemistry. State University. Ghent, Belgium.

Dong, T.; Shang, J.; Chen, J.M.; Liu, J.; Qian, B.; Ma, B.; Morrison, M.J.; Zhang, C.; Liu, Y.; Shi, Y.; Pan, H. and Zhou, G. (2019). Assessment of portable chlorophyll meters for measuring crop leaf chlorophyll concentration. Remote Sensing, 11(22): 2706. https://doi.org/10.3390/rs11222706.

Ehsanullah, M.; Tarapder, S.A.; Maukeeb, A.R.M.; Khan, A.U. and Khan, A.U. (2021). Effect of pinching on growth and quality flower production of chrysanthemum (*Chrysanthemum indicum* L.). Journal of Multidisciplinary Applied Natural Science, 1(2): 16-19. https://doi.org/10.47352/jmans.v1i2.15.

Falk, C.L.; van Voorthuizen, H.; Wall, M.M.; Guldan, S.J.; Martin, C.A. and Kleitz, K.M. (2000). An economic analysis of transplanting versus direct seeding of selected medicinal herbs in New Mexico, Journal of Herbs, Spices & Medicinal Plants, 7(4): 15-29. http://dx.doi.org/10.1300/J044v07n04_03.

Finch-Savage, W.E. and Bassel, G.W. (2016). Seed vigor and crop establishment: extending performance beyond adaptation, Journal of Experimental Botany, 67 (3): 567-591.

Foster, S. (1991). Echinacea: Nature's Immune Enhancer. Healing Arts Press.

Gavrić, T. and Omerbegović, O. (2021). Effect of transplanting and direct sowing on productive properties and earliness of sweet corn. Chilean Journal of Agricultural Research, 81(1): 1-10. https://doi.org/10.4067/S0718-58392021000100039.

George, A. (2004). Horticulture principles and practices. Published by Asoke K. Pp.709-710.

Halagi, M.S.; Maurya, R.P.; Bundela, M.K., and Jat, M.K. (2023). Effect of plant spacing and pinching interval on growth, yield and flower quality of African marigold (*Tagetes erecta* L.) under semi-arid conditions. The Pharma Innovation Journal, 12(4): 2246-2254.

Hudson, J.B. (2012). Applications of the phytomedicine *Echinacea purpur*ea (purple coneflower) in infectious diseases. Journal of Biomedicine and Biotechnology, 2012:1-16. https://doi.org/10.1155/2012/769896.

Ibrahim, F.R. (2017). Impact of pinching on growth and yield of marigold plant under potassium fertilizer combined with some stimulants. Current Science International, 6(4): 955-963.

Jena, S.; Mohanty, C.R.; Patra, C. and Dash, R.M. (2021). Effect of pinching on growth and flowering of annual chrysanthemum (*Chrysanthemum coronarium* L.). Journal of Pharmacognosy and Phytochemistry, 10(2): 1042-1045.

Jyothi, K.N.; Goud, C.R.; Girwani, A. and Kumar, T. (2018). Studies on the effect of planting dates and levels of pinching on growth, flowering and yield in marigold (*Tagetes erecta* cv. Arka Agni). International Journal of Current Microbiology and Applied Sciences, 7(11): 2705-2713. https://doi.org/10.20546/ijcmas.2018.711.309.

Ketema, S.; Dessalegn, L. and Tesfaye, B. (2013). Effect of planting methods on maturity and yield of onion (*Allium cepa* var cepa) in the Central Rift Valley of Ethiopia. Ethiopian Journal of Agricultural Sciences, 24(1): 45-55.

Kumar, M.; Prasad, V.M. and Bhardwaj, R. (2020). Study on effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under Prayagraj agro-climatic condition. International Journal of Chemical Studies, 8(5): 631-635. https://doi.org/10.22271/chemi.2020.v8.i5i.10372.

Lee, J.E.; Kim, K.S.; An, D. and Cha, Y.L. (2021). Effects of transplanting and direct seeding on the growth and yield of rapeseed (*Brassica napus* L.) during spring cultivation. Korean Journal of Crop Science, 66(4): 419-427. https://doi.org/10.7740/kjcs.2021.66.4.419.

Leskovar, D.I. and Othman, Y.A. (2021). Direct seeding and transplanting influence root dynamics, morpho-physiology, yield, and head quality of globe artichoke. Plants, 10(5): 1-15. https://doi.org/10.3390/plants10050899.

Malhotra, S.K. (2016). Recent advances in seed spices research–a review. Annals of Plant and Soil Research, 18(4): 300-308.

Mansouri, A.; Omidi, H. and Bostani, A. (2023). Effect of direct sowing, transplanting, priming and boron failor application on growth and yield of Quinoa genotypes. Journal of Crops Improvement, 25 (2): 469-484. https://doi.org/10.22059/jci.2022.343131.2709.

Melchart, D.; Linde, K.; Worku, F.; Bauer, R. and Wagner, H. (1994). Immunomodulation with Echinacea: A systematic review of controlled clinical trials. Phytomedicine, 1(3): 245-254. https://doi.org/10.1016/S0944-7113(11)80072-3.

Mohammed, A.H. (2019). Importance of medicinal plants. Research in Pharmacy and Health Sciences, 5(2): 124-125. https://doi.org/10.32463/rphs.2019.v05i02.01.

Murphy, J. and Riley, J.H. (1962). A modified single solution for the determination of phosphate in natural waters. Analytica Chimica Acta, 27:31-36.

Najm, W. and Lie, D. (2008). Dietary supplements commonly used for prevention. Primary Care, 35(4): 749-767. https://doi.org/10.1016/j.pop.2008.07.010.

Rahman, H.; Alam, M.; Nişhi, N.J. and Islam, M.S. (2022). Influences of transplanting approaches of propagation on growth, yield and economics of ginger (*Zingiber officinale* rose.) cultivation. Journal of Agricultural Sciences, 6(4): 752-761.

Rajput, V.; Abhisekh Kumar, J. and Tomar, S. (2020). Effect of pinching and spacing on growth parameters of African marigold (*Tagetes erecta* L.). Plant Archives, 20: 533-537.

Sathappan, C.T. (2018). Effect of plant growth regulators and pinching on growth and flower yield of African marigold (*Tagetes erecta* L.). J. Hortl. Sci., 13(1): 42-47.

Seckin, C.; Alpun Kalayci, G.; Turan, N.; Yilmaz, A.; Cizmecigil, U.Y.; Aydin, O. and Yilmaz, H. (2018). Immunomodulatory effects of *Echinacea* and *Pelargonium* on the innate and adoptive immunity in calves. Food and Agricultural Immunology, 29(1): 744-761. https://doi.org/10.1080/09540105.2018.1444738.

Singh, H.V.; Meena, M.K.; Choudhary, R.L.; Dotaniya, M.L.; Meena, M.D.; Jat, R.S.; Premi, O.P. and Rai, P.K. (2019a). Effect of direct sowing and transplanting on yield performance of Indian mustard. International Journal of Current Microbiology and Applied Sciences, 8(2): 509-515. https://doi.org/10.20546/ijcmas.2019.802.058.

Singh, R.; Meena, M.L.; Verma, S.; Mauriya, S.K.; Yadav, S.; Kumar, V.; Singh, V. and Maurya, S.K. (2019b). A review on effect of pinching on growth, flowering and flower yield of marigold. Indian Journal of Pure and Applied Biosciences, 7(4): 493-501. http://dx.doi.org/10.18782/2320-7051.7760.

Snedecor, G.W. and Cochran W.G. (1989). Statistical methods. 7th ed. Iowa State Univ. Press. Ames Iowa, USA.

Srivastava, R.K.; Kumar, S. and Sharma, R.S. (2018). Ocimum as a promising Commercial Crop. The Ocimum Genome. Springer. pp: 1-7.

Susila, T. and Reddy, G.S. (2017). Effect of direct sowing and transplanting on seed yield of babchi (*Psoralea corylifolia*). International Journal of Minor Fruits, Medicinal and Aromatic Plants, 3(1): 16-19.

Ur-Rahman, I. and Sher, H. (2019). Reference guide on high value medicinal and aromatic plants–

sustainable management and cultivation practices. University of Swat, Pakistan.

Vasiu, A.; Şandru, C.D.; Chanove, E.; Olah, D.I.; Pall, E.; Duca, G. and Spînu, M. (2023). Echinacea genus: an endless natural therapeutic resource? An overview. Current Perspectives on Medicinal and Aromatic Plants, 6(1): 51-65.

William H.C. and Rowley, E.M. (1992). 20-Bedding Plants, Editor(s): Roy A. Larson, Introduction to Floriculture (2nd Edition), Academic Press, pp. 511-550. https://doi.org/10.1016/B978-0-12-437651-9.50025-7.

Zheng, Y.; Dixon, M. and Saxena, P.K. (2006). Growing environment and nutrient availability affect the content of some phenolic compounds in *Echinacea purpurea* and Echinacea angustifolia. Planta Medica, 72(15): 1407-1414. https://doi.org/10.1055/s-2006-951720.