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Comparative Effect of Varieties and Types of Containers on Seed Germination and Seedling Growth of Geranium (*Palergonium graveolens*)

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Abstract: Geranium (*Pelargonium graveolens* L'Hér.) is an important commercial horticultural plant extensively used in outdoor landscaping. Seed emergence has always remained a problem in geranium due to its hard seed nature. Hence its germination and other emergence-related attributes need to be adequately tested. The purpose of this study was to evaluate the germination and seedling growth of geraniums under different types of containers. In this regard, the seeds of two varieties of geranium viz. Large FID mixed and Star mixed were planted in different types of containers. The containers included black trays plastic pots, plastic bags, and nonwoven fabric bags. The seed emergence and other germination related parameters were significantly affected by the different types of containers. However, varieties exhibited similar responses for most germination and growth characteristics. Data were collected for seed germination, mean germination time, germination index and seedling vigor index. The type of containers showed a significant impact on seedling growth and development. The taller plants with more leaves and maximum biomass production were recorded from seeds sown in nonwoven fabric type bags. The results pertaining to varieties demonstrated that Star mixed showed better emergence and vigorous seedlings in comparison with large FID mixed. The taller seedlings with maximum leaves and shoot biomass were also recorded from Star mixed grown in nonwoven fabric type bags. Based on the results, it is concluded that germanium may be raised in nonwoven fabric bags for better seed emergence and seedling growth and development.

Keywords: pelargonium; container type; seed germination; seedling growth

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1. Introduction

Geranium (*Pelargonium graveolens* L'Hér) is one of the choicest ornamental outdoor plants and belongs to the family Geraniaceae [1]. Geranium is an important, high-value perennial, aromatic herb and shrub that can reach to a height of 1.3 m and a spread (lateral growth) of 1 m. Its hairy stems are herbaceous when young and become woody with age, and the plant's leaves are deeply incised, soft to the touch, and strongly rose scented [2–4]. The geranium are native to South Africa [5]. It is not to be confused with the household variety of geranium, which is a completely different species. There are over 700 varieties of cultivated geranium, however, most are grown for ornamental purposes. Moreover, geranium plants come in a variety of colors, white, pink, salmon, red, fuchsia, lavender, leaf patterns, round, segmented, lacy, flower size, single or double bloom, and leaf color, green, green and white, or multicolored. Geranium plants can be compact upright plants or graceful hanging vines. The vibrant Geranium flowers do not have an appealing aroma, but there are several Geranium varieties that have leaves with lovely scents such as rose, lime, peppermint, lemon, orange, or lime [6]. Geranium Plants are a great addition to your indoor plant collection, but will only bloom if you keep them in very bright light or direct sun for at least 6–8 h a day.

The type of containers play a significant role for successful seed emergence of plant species [6,7]. Containerised seedling production has been widely used since the early sixties. This practice improved seedling survival and management as compared to bare-root seedling production [7]. The primary function of any container is to hold a discrete supply of growing medium, which in tum supplies water, air, mineral nutrients and physical support to the seedling [8]. Container based production of floriculture plants has competitive advantage over conventional (field) production. The advantages that are linked to container production included the less damage to root system of plants during the transplanting process and rapid establishment of root after transplantation. Moreover, less labour and land acquirement cost and increased availability and longevity of plant production in the market, all are the benefits of container production. In container plantation, plants are grown and transplanted with intact and functional root system thus enhancing the prospective of success ratio of transplanting.

Nursery practices are considered to have a large impact on seedling root development and this effect is likely to be maintained during the early establishment phase [9]. The characteristics of the nursery culture and particularly the container type is among the most important determinants of seedling production and its quality [10]. Besides that, container design also determines the morphological and physiological characteristics of seedlings, mainly in terms of their root systems [11–13]. Moreover, container volume and container depth can determine root system growth including emergence of new roots and their length and survivability of seedlings as well [14–17].

Containers for the raising of the seedlings come in various forms, sizes, and in different materials such as polystyrene, polyethylene, root trainers, fiber, or paper. A common problem with all containers is the substrate. However, it is important to note that in developing countries like Pakistan the most commonly used substrates are soil and sand-based mixtures which are unsuitable for the development of an extensive fibrous root system. This type of substrate creates problems in various types of containers such a common problem with polybags is observed that plant roots tend to grow in spirals once they hit the smooth inner surface and root systems that lead to root girdling and weak performance after out planting [18]. This inevitably leads to plants with restricted growth, poor resistance to stress and wind throw, and even early dieback due to ensnarled root masses or pathogens. This is a major drawback of the use of conventional polybags. As an alternative, root trainers are usually rigid containers with internal vertical ribs, which direct roots straight down to prevent spiral growth [19,20].

The type of container selected for growing depends on the plants to be raised [21]. The most common container used for seedling production is black plastic trays [22]. The black color has been found to absorb solar radiation and increase substrate temperatures [23]. The ideal container for nursery plants should have an attractive appearance, structural strength, and good insulation value, the material should not be brittle or decompose rapidly, good durability during handling and shipping, promotes a healthy root system [24]. Moreover, the container should be, light in weight, provide good drainage, be long-lived and affordable, creates no hazard for customers during planting and ease of disposal (sustainability) of product. Container type can significantly affect the root morphology of container-grown plants [25]. By keeping all in mind, the present study is therefore designed to observe seed germination and seedling growth of the geranium in different types of containers.

2. Materials and Methods

2.1. Experimental Site

The experiment was performed during 2019, at the experimental field of Department of Horticulture, Sindh Agriculture University Tandojam, Pakistan. The experimental site lies at 28°35′ N to 81°37′ E.

2.2. Weather Conditions

Weather conditions of the experimental site four different seasons: rainy monsoon (June–October), cold winter (November–February), and warm spring (March–May). Trial was performed during winter season and plants were grown upto to months in containers and placed in shade house.

2.3. Experimental Set Up

The seeds of two varieties of geranium (*Pelargonium graveolens* L'Hér) viz. (Large FID mixed and Star mix) were sown in different types of containers containing canal sediments to observe the efficacy of the containers in terms of the best seed germination and seedling growth. Thirty seeds of each variety were grown in different types of containers. The mixture of the growing medium was filled in containers by leaving approximately one-inch space at the top. The container types included viz.C_1 = black trays, C_2 = plastic pots, C_3 = plastic bags, C_4 = nonwoven fabric bags. The experiment was run in a completely randomized design (CRD) with three replications.

2.4. Procedure for Observations

2.4.1. Seed Germination (Percentage)

The seed germination was regularly checked up to one week of plantation and germination (%) was calculated by using the following formula (Larsen and Andreasen, 2004).

$$GP = \sum n/N \times 100 \tag{1}$$

where *GP* is germination percentage, *n* is number of seeds germinated and *N* is total number of seeds planted.

2.4.2. Mean Germination Time (Days)

Mean germination time was calculated by using the following equation of Ellis and Roberts (1981).

$$MGT = \sum Dn/\sum n \tag{2}$$

where *MGT* is mean germination time, *Dn* days to germinate *n* number of seeds and *n* is total number of seeds germinated.

2.4.3. Germination Index (GI)

The GI was calculated by the formula given by the Association of Official Seed Analysts (1983).

$$GI = \frac{Number\ of\ germinated\ seeds}{Days\ of\ first\ count} + \frac{Number\ of\ germinated\ seeds}{days\ of\ last\ count}$$

2.4.4. Seedling Vigor Index (SVI)

The seedling vigor index was calculated by following the formula (Abdul-Baki and Anderson, 1970).

$$\text{Seedling Vigor index (SVI)} = \text{Seedling length (cm)} \times \text{Germination percentage}$$

2.4.5. Fresh and Dry Biomass of Shoot and Roots

Biomass of the shoot and roots from twenty random seedlings was measured by using an electronic top loading balance.

2.4.6. Number of Leaves per Plant Was Counted from Five Random Samples of Each Treatment and Their Averages Were calculated

2.5. Data Analysis

The data was statistically analyzed using Statistix 8.1 computer software (Statistix, 2006). The comparison of the mean among treatments was tested by applying least significant difference (LSD) test.

3. Results

3.1. Effect of Type of Containers on Germination Related Attributes

3.1.1. Seed Germination

The seed germination of geranium was significantly affected by the different types of containers. However, geranium varieties had no significant effect on seed germination. The interaction of both factors was also at par ($p < 0.05$). The data in (Table 1) depicted that the highest mean seed germination (86.83%) was observed from nonwoven fabric containers followed by seeds sown in Black trays that resulted in average seed germination of 70.33. However, the minimum seed germination of 38.67% was observed in Plastic pots. The means of the geranium varieties range seed germination from 63.42% to 65.67%. While an interactive effect of geranium varieties and types of containers ranges seed germination from 38% to 89.67%.

Table 1. Effect of different types of containers on seed germination of geranium.

Type of Container	Varieties		Mean (Germination %)
	Large FID Mixed	Star Mixs Star Mix	
Black plastic trays	71.00	69.67	70.33 B
Plastic pots	39.33	38.00	38.67 D
Plastic bags	62.67	62.00	62.33 C
Nonwoven fabric bags	89.67	84.00	86.83 A
Mean (germination %)	65.67	63.42	
	Variety (V)	**Container (C)**	**V × C**
S.E±	2.3467	3.3187	4.6934
Probability	0.3519	0.0000	0.8671
LSD 0.05	4.9748	7.0344	9.9495

Values in each column having same letter, does not significantly different from each other.

3.1.2. Germination Time (Days)

The results regarding germination time illustrated that type of containers had significant impact on germination time, while varieties are not significantly different from each other. The interactive effect of the varieties and type of containers had also significant differences ($p < 0.05$) for days to germination. The data in (Table 2) depicts that early germination (3.67 days) was observed from the seeds grown in nonwoven fabric bags. These results are at par with the results (4.67 days) obtained from the seeds grown in plastic trays. The seeds sown in plastic bags and plastic pots took more time in emergence and showed 7.33 days and 9.83 days, respectively. The interaction results showed that minimum germination time for seed emergence (3.67) was observed from Large FID mixed grown in nonwoven fabric bags. The maximum germination time (10.67 days) was noted in Star mixed grown in plastic pots.

Table 2. Effect of different types of containers on mean germination time (days) of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	**Star Mixs Star Mix**	
Black plastic trays	4.00 ef	5.33 de	4.67 C
Plastic pots	9.00 b	10.67 a	9.83 A
Plastic bags	8.00 bc	6.67 cd	7.33 B
Nonwoven fabric bags	3.67 f	3.67 f	3.67 C
Mean	6.17	6.58	
	Variety (V)	**Container (C)**	**V × C**
S.E±	0.3727	0.5270	0.7454
Probability	0.2801	0.0000	0.0442
LSD 0.05	0.7900	1.1173	1.5801

Values in each column having same letter, does not significantly different from each other.

3.1.3. Germination Index (GI)

The results regarding the germination index are presented in (Table 3). The germination index was significantly ($p < 0.05$) affected by the varieties and containers and the interactive effect of the varieties and containers was non-significant ($p < 0.05$). The data in Table 3 depicts those plants emerged from seeds sown in nonwoven fabric bags had a maximum germination index (6.83) followed by plants grown in plastic bags that showed germination index (6.50). However, results obtained from nonwoven fabric bags and plastic bags had statistically similar seed germination indexes. The seeds grown in black trays and plastic pots had minimum and similar germination index i.e., 4.33 and 4.17, respectively. To compare varieties, large FID mixed had a better germination index (6.00) as compared to star mix (4.92).

Table 3. Effect of different types of containers on germination index of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	**Star Mixs Star Mix**	
Black plastic trays	4.67	4.00	4.33 B
Plastic pots	4.67	3.67	4.17 B
Plastic bags	7.00	6.00	6.50 A
Nonwoven fabric bags	7.67	6.00	6.83 A
Mean	6.00 A	4.92 B	
	Variety (V)	**Container (C)**	**V × C**
S.E±	0.3005	0.4249	0.6009
Probability	0.0024	0.0000	0.6960
LSD 0.05	0.6370	0.9008	1.2739

Values in each column having same letter, does not significantly different from each other.

3.1.4. Seedling Vigor Index

The results regarding seedling vigor index demonstrated that type of containers had a notable effect on the seedling vigor index (Table 4). The varieties and the interaction between varieties and type of containers also revealed significant influence ($p < 0.05$) on seedling vigor index. The seedling vigor index ranged from 462.4 to 1793.6. The maximum seedling vigor index was found in seedlings emerged from seeds sown in nonwoven fabric bags. The seeds raised in black plastic trays and plastic pots had similar results for seedling vigor index i.e., 533.2 and 462. 4, respectively. The seeds of Large FID mixed, and Star mix produced similar results for the seedling vigor index that ranged from 901.26 to 992.33.

Table 4. Effect of different types of containers on seedling vigor index of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	Star Mixs Star Mix	
Black plastic trays	531.9	534.6	533.2 C
Plastic pots	484.3	440.5	462.4 C
Plastic bags	1062.9	933.1	998.0 B
Nonwoven fabric bags	1890.2	1696.9	1793.6 A
Mean	992.33	901.26	
	Variety (V)	**Container (C)**	**V × C**
S.E±	52.814	74.690	105.63
Probability	0.1039	0.0000	0.5732
LSD 0.05	111.96	158.34	223.92

Values in each column having same letter, does not significantly different from each other.

3.2. Effect of Type of Containers on Growth Related Attributes

3.2.1. Fresh and Dry Shoot Biomass

The fresh and dry biomass of the shoot was significantly affected by the type of containers. While geranium varieties and interaction of the geranium varieties and type of containers had no significant effect on shoot biomass production (Table 5). The fresh and dry biomass of the shoot ranged from 0.97 g to 3.74 g and 290 mg and 1660 mg, respectively (Table 5). The maximum fresh biomass and dry biomass of shoot was observed from the seedlings raised in nonwoven fabric bags followed by the seedlings raised from seeds sown in plastic bags and plastic pots, respectively. The seeds raised in black plastic trays had seedlings with minimum fresh biomass The interaction results showed that maximum shoot biomass production was noted in variety Star mix. However geranium varieties had non-significant differences for fresh and dry shoot biomass.

Table 5. Effect of different types of containers on fresh biomass of shoot (g) of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	Star Mixs Star Mix	
Black plastic trays	0.93	1.02	0.97 D
Plastic pots	1.43	1.38	1.40 C
Plastic bags	2.53	2.82	2.67 B
Nonwoven fabric bags	3.66	3.82	3.74 A
Mean	2.14	2.26	
	Variety (V)	**Container (C)**	**V × C**
S.E±	0.0988	0.1397	0.1976
Probability	0.2360	0.0000	0.6687
LSD 0.05	0.2095	0.2962	0.4189

Values in each column having same letter, does not significantly different from each other.

3.2.2. Dry Biomass of Shoot (mg)

The results regarding dry shoot biomass are presented in Table 6. The dry biomass of the shoot was significantly different due to the different types of containers. While geranium varieties had no significant differences for dry biomass of shoot. However, the interaction of varieties and type of containers was not significantly different for dry biomass of shoot ($p < 0.05$). The seedlings raised in black plastic trays had minimum dry biomass of shoot (290 mg) that was increased in plastic pots up to 590 mg. The maximum dry biomass of the shoot (1660 mg) was observed from the seedlings raised in nonwoven fabric bags. However, the seedlings raised in plastic bags had 1200 mg dry biomass of shoot. To compare geranium varieties, the Large FID mixed variety produced 920 mg dry biomass of shoot that is similar to star mix (950 mg). On the basis of the interaction of geranium varieties and type of containers, the dry biomass of shoot ranges from 240 mg to 1670 mg.

Table 6. Effect of different types of containers on dry biomass of shoot (mg) of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	**Star Mixs Star Mix**	
Black plastic trays	240	350	290 D
Plastic pots	560	630	590 C
Plastic bags	1230	1180	1200 B
Nonwoven fabric bags	1650	1670	1660 A
Mean	920	950	
	Variety (V)	**Container (C)**	**V × C**
S.E±	0.0862	0.1218	0.1723
Probability	0.6899	0.0000	0.9211
LSD 0.05	0.1826	0.2583	0.3653

Values in each column having same letter, does not significantly different from each other.

3.2.3. Fresh and Dry Root Biomass

Fresh and dry root biomass of both the varieties were significantly varied in response to the different type of containers. The analysis of variance shows that both the factors viz. varieties and container types as well as their interactions showed highly varied response to fresh and dry biomass production (Table 7). The data showed that maximum fresh root biomass (238.67 mg) and dry root biomass (45.83 mg)was observed from Large FID mixed seedlings raised in nonwoven fabric bags followed by the results (153.67 mg) and (38.83 mg) in star mix from same type of container. The results related to containers reflected that, maximum fresh and dry biomass of roots (196.17 mg) and (66.67 mg) was observed from the seedlings raised in nonwoven fabric bags followed by the results (138 mg) and (47.83 mg) from plastic bags. The results of the plastic bags and plastic pots are statistically similar for fresh biomass of the roots.

Table 7. Effect of different types of containers on fresh root biomass (g) of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	**Star Mix Star Mix**	
Black plastic trays	46.67 de	41.00 e	43.83 C
Plastic pots	126.33 bc	89.00 cd	107.17 B
Plastic bags	135.33 bc	140.67 b	138.00 B
Nonwoven fabric bags	238.67 a	153.67 b	196.17 A
Mean	136.75 A	106.08 B	
	Variety (V)	**Container (C)**	**V × C**
S.E±	11.131	15.741	22.262
Probability	0.0141	0.0000	0.0471
LSD 0.05	23.596	33.370	47.193

Values in each column having same letter, does not significantly different from each other.

3.2.4. Dry Root Biomass (mg)

The results regarding dry root biomass are presented in (Table 8). The dry root biomass was significantly affected by the type of containers while geranium varieties had no significant differences for dry root biomass. The interaction of geranium varieties and type of containers had also no significant differences for dry biomass of roots. To compare means of the containers, nonwoven fabric bags (66.67 mg) were observed potential bags for maximum dry biomass of roots. These results are at par with the results obtained from the seedlings grown in plastic bags (47.83 mg). The seedlings raised in black plastic trays (22.50 mg) and plastic pots (32.33 mg) produced seedlings with similar dry biomass of roots. About geranium varieties, Large FID mixed (45.83 mg) produced seedlings with similar dry biomass of the roots as in Star mix (38.83 mg). On the basis of interaction of varieties and type of containers, dry biomass of roots ranges from 21.67 to 76.67 mg.

Table 8. Effect of different types of containers on dry root biomass (mg) of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	Star Mix Star Mix	
Black plastic trays	21.67	23.33	22.50 C
Plastic pots	34.33	30.33	32.33 BC
Plastic bags	50.67	45.00	47.83 AB
Nonwoven fabric bags	76.67	56.67	66.67 A
Mean	45.83	38.83	
	Variety (V)	**Container (C)**	**V × C**
S.E±	7.0406	9.9569	14.081
Probability	0.3349	0.0000	0.7353
LSD 0.05	14.925	21.108	29.851

Values in each column having same letter, does not significantly different from each other.

3.2.5. Number of Leaves per Seedlings

Different type of containers had significant effect on leaves per seedling. The interaction of geranium varieties and type of containers also revealed notable effect of leaves of seedlings The number of leaves per seedling ranged from 6.67 to 36.33 (Table 9). The results regarding the number of leaves per seedlings reflected that the type of containers had a greater influence on the germination and seedling growth of geranium. The maximum leaves (35) were recorded from the seedlings raised in nonwoven fabric bags. These results are significantly different from the seedlings raised in plastic bags that produced less leaves (25.17) leaves in individual seedlings. The minimum number of leaves per seedling (7) was observed from the seedlings raised in black plastic trays. Same trend was observed in geranium varieties, Star mixed significantly produced more leaves (22.17) than Large FID mixed that showed (19.25) leaves per seedling grown in nonwoven fabric bags.

Table 9. Effect of different types of containers on the number of leaves per seedlings of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	Star Mixs Star Mix	
Black plastic trays	7.33	6.67	7.00 D
Plastic pots	15.33	16.00	15.67 C
Plastic bags	20.67	29.67	25.17 B
Nonwoven fabric bags	33.67	36.33	35.00 A
Mean	19.25	22.17	
	Variety (V)	**Container (C)**	**V × C**
S.E±	1.5964	2.2577	3.1929
Probability	0.0864	0.0000	0.1882
LSD 0.05	3.3843	4.7861	6.7686

Values in each column having same letter, does not significantly different from each other.

3.2.6. Seedlings Height (cm)

The same trend of the results was observed for the height of the seedlings Different type of containers revealed a notable effect on seedling height; however, the varieties and the interaction results exhibited a non-insignificant ($p < 0.05$) result. The data in Table 10 shows that the mean height of the seedlings ranges from 7.63 to 20.62 cm. The seedling raised in nonwoven fabric bags had seedlings of maximum height (20.62 cm). These results are significantly different from the results obtained from plastic bags (15.97 cm), plastic pots (12.07 cm), and black plastic trays (7.63 cm). In case of geranium varieties, taller plants were observed in Large FID mix. Moreover, interaction between varieties and type of container revealed that Large FID had maximum seedling height grown in nonwoven fabric box (Table 10) On the basis of the interaction of geranium varieties and type of containers, seedling height ranges from 7.56 cm to 21.08 cm.

Table 10. Effect of different types of containers on the height of seedlings (cm) of geranium.

Type of Container	Varieties		Mean
	Large FID Mixed	Star Mixs Star Mix	
Black plastic trays	7.56	7.69	7.63 D
Plastic pots	12.32	11.84	12.07 C
Plastic bags	16.90	15.04	15.97 B
Nonwoven fabric bags	21.08	20.17	20.62 A
Mean	0.18	0.07	
	Variety (V)	**Container (C)**	**V × C**
S.E±	0.5630	0.7961	1.1259
Probability	0.1849	0.0000	0.6542
LSD 0.05	1.1934	1.6877	2.3868

Values in each column having same letter, does not significantly different from each other.

4. Discussion

Nursery practices are considered to have a large impact on seedlings root development during the nursery phase, this effect is likely to be maintained the early establishment phase [9]. The characteristics of the nursery culture and particularly container types are among the most important determinants of the cost of seedling production, as well as of seedling quality [10]. The ideal container for nursery plants should possess attractive appearance, structural strength, the material should not be brittle or decompose rapidly, good durability during handling and shipping, promotes a healthy root system, efficient storage (nesting) potential, light in weight and provide good drainage. Moreover, container be long-lived and affordable, create no hazard for customers during planting and ease of disposal (sustainability) of product. It is important to note that plants don't grow in containers naturally, so this environment is unnatural and different from field-grown or native conditions [26].

Different type of containers plays a significant for seed emergence and healthy growth and development of seedlings [24]. In general, a relationship has been observed between container size or shape and seedling growth [27]. The use of deep containers in the nursery does not necessarily produce excessive height, growth, adequate control of watering and fertilization could modulate seedling height and growth [28].

The most common container used for nursery production is the black plastic container, while these containers tend to be inexpensive (though cost depends on current petroleum prices), they have benefits and drawbacks. Black plastic containers are lightweight, durable, familiar to growers, well-suited for mechanization, and can be reused or recycled. These containers are made from many different plastic types, melted and remolded for the desired shape and size. In the present study different types of containers were used to observe germination and seedling growth of geranium. Nonwoven fabric bags were observed as the best container for germination and seedling growth of geranium. The use of nonwoven fabric bags was observed better for transplantation of the seedlings as these bags can be transplanted directly in containers or soil without removing the bag, reducing the risk of damage to the roots during the moment of transplanting. Similar reports were also observed by the [29]. These bags are made from natural fibers such as grasses, cotton, sisal, etc. [30] reported that biodegradable containers required more frequent watering than those in polythene bags under light tree shade and shade nets but less frequent in polythene chambers. Seedlings produced in polythene tubes had higher growth rates in the nursery, but when transplanted to the field, they were overtaken by those grown in the biodegradable containers due to transplanting shock after the polythene containers were removed. In a study, better seedling growth observed in 600 mL and 1500 mL polybags than in the 1000 mL polybag [31]. This might be due to a greater ratio between length and diameter in the 1000 mL polybags (2.00) compared with the 600 mL (1.57) and 1500 mL (1.60).

With the development and improvements made in production technologies, nonwoven geotextiles are gaining more and more advantages over traditional agro textiles [32]. Nonwoven agro textiles are used effectively for optimizing the productivity of crops, gardens, and greenhouses. Some examples where nonwovens are used are as crop covers, plant protection, seed blankets, weed control fabrics, greenhouse shading, root control bags, biodegradable plant pots, capillary matting, landscape fabric, lawn coverings, bio-based and compostable nonwovens for multi-season mulching and other short-term and long-term agricultural applications [33]. Nonwoven fabrics present many advantages over conventional fabrics with one main clearest benefit, cost savings. Properties of nonwoven agro textiles depend on the fibers made of and on the type and conditions of production. The nonwoven agro textile can be made from natural or man-made fibers and their blends. As a natural fiber, jute is mostly used, while polypropylene is the most common choice for nonwoven agro textiles made from man-made fibers. [34] reported that the use of deeper containers produced seedlings with better above-ground characteristics. [12] reported that white or light containers have the potential to reflect solar radiation and eliminate heat stress. He said heat-sensitive plants will benefit from being grown in white containers or painting the outside of the container white for improved root growth. [20] observed that plastic containers were better than polybags. Seedlings produced in black plastic containers had a total dry weight of 1.8 g, shoot dry weight of 0.96 g, root dry weight of 0.89 g, and quality index of 0.23.

Different types of containers are used for successful production of ornamental plants [35]. Container size is a vital for satisfactory growth and development of nursery plants [36]. It has been widely reported that small size pots/container had a negative effect on plant growth and biomass production [37]. Since small size pots comprises of less amount of soil that causes reduced availability of water and nutrients to the plants. Thus, eventually lead to poor growth and development of plants [38]. Pot/container also effect the photosynthetic activity in plants. Available evidences have revealed that low photosynthetic rate was observed in small size plants [39]. Since small sized pots contains small fraction of soil in which plant nutrients quantity specially nitrogen and phosphorus is decreased [40]. Nitrogen and phosphorus are vital for enhancing the photosynthetic rate [41]. The low photosynthetic rate in the small sized pots might be attributed to less contents of nitrogen and phosphorus in the soil [42].

5. Conclusions

Based on the results of this study, it has been concluded that different types of containers have an impact on the germination and growth of geraniums. Compared to woven fabric bags, nonwoven fabric bags resulted in better seed germination and seedling growth. In case of varieties, Large FID mixed produced better germination index and biomass production. These results highlight the importance of container selection for seed emergence and seedlings growth of geranium and offer new insights about the future application of containers for diverse ornamental crop species.

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