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Effect of Soil Propagation Media and Bio-fertilizers on Seedling Germination and Seedling Vigour in Aonla (*Emblica officinalis* Gaertn.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims/ Objectives: Effect of soil propagation media and bio-fertilizers on seedling germination and seedling vigour in Aonla.
Study Design: Completely Randomized Block Design.

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Place and Duration of Study: Research Field, Department of Fruit Science, College of Horticulture, Mandsaur, Madhya Pradesh during 20th February 2021 to 05th April 2021.
Methodology: The experiment was laid out using Completely Randomized Block Design with 18 different combinations of growing media. In the preparation of media and filling of polybags the soil was sieved and mixed FYM, Vermicompost and Neemcake in the ratio of 1:1:1:1 then added the bio-fertilizers.
Results: In this study we found that treatment GM_{18}- Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp*. @ 2.5 g found minimum days taken to seed germination (10.00 days), maximum number of seedling sprouted (13.32), maximum survival percent (81.03 %), maximum germination percentage (94.54 %), maximum seedling height (8.94 cm), maximum number of leaves per plant (7.27), maximum leaf area (17.80 cm^2),maximum fresh weight of shoot (4.34 g), maximum dry weight of shoot (2.21 g), maximum length of roots (7.21 cm), maximum diameter of roots (1.05 mm), maximum fresh weight of roots (1.04 g), maximum dry weight of root (0.44 g), maximum speed of germination (7.56), maximum mean daily germination (3.53), maximum peak value (1.33), maximum germination value (4.68).
Conclusion: On the basis of results obtained in present investigation it is concluded that treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp*. @ 2.5 g) was found to be the best for seed germination characters and seedling vigour characters.
Directions of Further Use: The experiment should be done with different concentrations of growth regulator to find the best combination.

Keywords: Aonla; bio-fertilizers; germination; media and propagation.

1. INTRODUCTION

"Aonla *(Emblica officinalis* Gaertn.*)* is one of the most important indigenous fruit of arid tropics it belongs to the family Euphorbiaceae originated in Tropical southeastern Asia. It is also known as Indian gooseberry. Aonla is a much branched tree which is small to medium in size and shows evergreen behavior in tropics and deciduous in subtropical conditions. The plant is winter hardy and can be grown successfully in arid and semi arid regions and in soils with high pH and on waste lands" [1].

"Aonla is one of the best fruit which is being used in various ways thus, fresh aonla based products are being imported by different countries from India. Aonla is rich source of Vitamin C (600mg/100gm). It is used for making murabba and chutney. The other products are sauce, candy, dried chips, tablets, jelly, jam, pickle, powder etc. it is also used in Ayurveda for preparation of *Triphala* and *Chyavanprash"* [2].

Aonla has been raised from seeds for long. Seed propagation of aonla has demerits of lacking true to type plants; the growth of aonla seedling very slow and take more time to attain buddable stage. Aonla is mainly propagated by Patch budding. The quality rootstock are very important for success of budding of various methods of vegetative propagation, patch budding, shield budding, grafting, top working are the methods of aonla propagation, [2].

For propagation of aonla seeds propagation media is needed. Propagation media provides initial support and all the suitable conditions needed for the growth of the plant or tissue. It provides nutrition for the growing plant or tissue. Its primary function is to hold the water and nutrition for the root uptake. Propagation media also provide adequate root aeration and also maintain the structure of the growing plant, [3].

"Qualities of a good propagation media includes, the medium should be firm enough to hold propagating material, it should have ability to retain and supply sufficient moisture, it should have sufficient nutrition for the growth of plant *etc*. Supplementing of the sand is aimed to make media more porous while the organic matter (FYM, sheep manure, neemcake and vermicompost) is added so as to enrich adequate nutrient for the seedling" [3].

"The garden soil is usually used as a basic medium because it is topsoil, enriched with compost and other organic matter so it's nutritious for plants. It has a heavier texture and holds water longer; it doesn't have pricier ingredients like perlite, vermiculite or moss" [4].

"FYM supplies all major nutrients (N, P, K, Ca, Mg, S,) necessary for plant growth, as well as

micronutrients (Fe, Mn, Cu and Zn). FYM improves soil physical, chemical and biological properties, production of antibiotics and biodegradation of organic matter in the soil providing better nutrient uptake and increased tolerance towards drought and moisture stress" [5].

"Vermicompost probably contributed to the increased seed germination and growth. It maintains the soil in a proper homeostatic state. It also removes excessive amounts of heavy metals such as copper and lead and there by served as a means of detoxification, [6]. Vermicompost could promote early and vigorous growth of seedlings. It has been found to effectively enhance the root formation, elongation of stem and production of bio- mass" [7].

"Rhizobacteria promote plant growth serve a vital role in enhancing metabolic activity in germinating seeds and safeguarding seeds and seedlings through a variety of processes, including antibiotic synthesis and siderophores generation. Thus, resulting in early and higher rate of germination. Further, these *Rhizobacteria* stays in association with root, fix atmospheric nitrogen, increases the availability and uptake of phosphorus and other nutrients in addition to production of plant growth regulators" [8].

"Trichoderma viridae is a well-known bio-fungicide fertilizer fungus. It can be used for the treatment and overpowering of seed and soil diseases caused by similar strains of the disease-causing organism. *T. viridae* acts as a bio-fertilizer. When it's applied to the potential growing crop, it improves seed sprouting level" [9].

2. MATERIALS AND METHODS

2.1 Experimental Site

The study was conducted during Research Field, Department of Fruit Science, K.N.K. College of Horticulture, Mandsaur, Madhya Pradesh, India during the year February 2021 to April 2021. The Field is situated at 23.45^0 to 24.13^0 N latitude and 74.44^0 to 75.18^0 E longitude at an altitude of 435 m Mean Sea Level.

2.2 Experimental Details

The experimental design chosen for the experiment was Completely Randomized Design. The treatments in experiment were replicated three times and each treatment consisted of 15 polybags. Size of polythene bags is 13 cm × 7 cm which contain 0.50 kg of media mix was used for experiment. Mean separation was performed using Duncan's multiple range test at 5% level. Aonla seeds were procured from the local market, Biofertilizer (*Rhizobium and Trichodarma spp.*) and rooting media (Vermicompost, Soil, FYM and Neemcake) is also purchased from local market (Mandsaur). Size of polythene bags is 13 cm × 7 cm which contain 0.50 kg of media mix was used for experiment. GM_1- Soil, GM_2- Soil + Neemcake, GM_3- Soil + Vermicompost, GM_4- Soil + FYM, GM_5- Soil + Neemcake + Vermicompost, GM_6- Soil + *Rhizobium*, GM_7- Soil + *Trichoderma spp.* @2.5g, GM_8- Soil + Neemcake + *Rhizobium*, GM_9- Soil + Vermicompost + *Rhizobium*, GM_{10}- Soil + FYM + *Rhizobium*, GM_{11}- Soil + Neemcake + *Trichoderma spp.* @2.5g, GM_{12}- Soil + Vermicompost + *Trichoderma spp.* @2.5g, GM_{13}- Soil + FYM + *Trichoderma spp*.@ 2.5g, GM_{14}- Soil + Neemcake + FYM, GM_{15}- Soil + Neemcake + Vermicompost + *Trichoderma spp.* @ 2.5g, GM_{16}- Soil + Neemcake + Vermicompost + *Rhizobium*, GM_{17}- Soil + FYM + Vermicompost, GM_{18}- Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp*. @ 2.5g.

2.3 Preparation of Media and Filling of Polybags

Sieve the soil, FYM, Vermicompost and Neemcake and mixed properly in the ratio of 1:1:1:1 then added the biofertilizers *i.e.Trichoderma* and *Rhizobium* as per treatment,mixed thoroughly and moisture, then cover by polyethylene sheet, kept the media whole night for better growth of culture. The experiment was carried out by sowing seeds in 13 cm × 7 cm size polythene bags. Fill the polybags according to treatments wise and put at place were experiment to be done. Two seeds per poly bag were sown on last week of February, 2021 at the depth of 1-2 cm. Then polybags were covered by white polythene sheet for uniform and early germination. After sowing of seeds, fine spray of water was done with help of "Hazara" (water cane) in such a way that water soaked to the bottom of bags. For rest of period, watering was done regular interval to keep the soil always moist conditions.

2.4 Observations Recorded

2.4.1 Germination percentage

Germination percent was recorded by counting the germinated seeds till germination process completed (up to 45 days of sowing) and germination percent was calculated by using the following formula [1]

$$\text{Germination } (\%) = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100$$

2.4.2 Survival percent

Survival percent was recorded by counting the survived plant after germinated (after 30 days or up to 45 days of sowing) and survival percent was calculated by using the following formula [10].

$$\text{Survival } (\%) = \frac{\text{Number of survived plants}}{\text{Total number of germinated seeds}} \times 100$$

2.4.3 Speed of germination

Speed of germination was calculated by the following formula [2].

Speed of germination= $n_1/d_1 + n_2/d_2 + n_3/d_3$+……...

Where,

n= number of germinated seeds,
d= number of days.

2.4.4 Mean daily germination

Mean daily germination can be calculated by the following formula; [3].

$$\text{MDG} = \frac{\text{Total number of germinated seeds}}{\text{Total number of days}}$$

2.4.5 Peak value

Peak value was calculated by the following formula given by [11].

$$\text{PV} = \frac{\text{Highest seed germinated}}{\text{Number of days}}$$

2.4.6 Germination value

Germination value was calculated by the following formula [11].

GV = Peak value x Mean daily germination

3. RESULTS

3.1 Seed Germination Characters

3.1.1 Days taken to seed germination

Statistically analyzed data presented in Table 1 indicated that days taken to seed germination was significantly influenced by the application of different propagation media and biofertilizers over treatment GM_1 (soil). It was noticed that the significantly minimum days taken to seed germination was (10.00 days) seen under treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g) over the rest of the treatments. Although, the treatment GM_{16} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium*) 10.03 days was *at par with* the treatment GM_{18}. While, maximum days taken to germination (13.33 days) was found with the treatment GM_1 (Soil).

3.1.2 Number of seedling sprouted

Data revealed that the various treatments had significantly influenced the number of seedling sprouted in all the treatments except GM_1 (soil). However, maximum number of seedling sprouted (13.32) was found with the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). While, minimum number of seedling sprouted (11.04) was recorded under the treatment GM_1 (Soil).

3.1.3 Germination percentage

Statistically analysed data indicated that the data recorded due to the effect of propagation media and biofertilizers was significant over soil media. The maximum germination percentage (94.54%) was found with the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). Whereas, the minimum germination percentage (74.70%) reported by the treatment GM_1 (Soil).

3.1.4 Survival percentage (%)

Data showed that significantly maximum survival percent (81.03%) was obtained by the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). Whereas, minimum survival percent (64.66%) was registered under the treatment GM_1 (Soil).

Table 1. Effect of soil propagation media and bio-fertilizers on days taken to seed germination, number of seedling sprouted, germination percentage (%), survival percentage (%), seedling height (cm), number of leaves per plant and leaf area (cm^2) in Aonla

Treatments		Days taken to seed germination	Number of seedling sprouted	Germination percentage (%)	Survival percentage (%)	Seedling height (cm)	Number of leaves per plant	Leaf area (cm^2)
GM_1	Soil	13.33	11.04	74.70	64.66	5.81	4.00	12.20
GM_2	Soil + Neemcake	12.53	11.47	76.66	66.89	6.03	4.13	14.74
GM_3	Soil + Vermicompost	12.67	11.58	78.05	67.89	6.11	4.34	15.23
GM_4	Soil + FYM	12.73	11.23	75.66	65.83	5.97	4.06	13.44
GM_5	Soil + Neemcake + Vermicompost	12.33	11.98	82.80	70.80	6.68	5.02	15.76
GM_6	Soil + *Rhizobium* +	12.47	11.83	80.44	70.05	6.45	4.94	15.63
GM_7	Soil + *Trichoderma spp.* @ 2.5g	12.60	11.62	78.74	68.55	6.22	4.76	15.47
GM_8	Soil + Neemcake + *Rhizobium*	10.67	12.68	93.49	79.01	7.18	6.44	17.06
GM_9	Soil + Vermicompost + *Rhizobium*	10.47	12.87	93.71	79.20	7.80	6.76	17.19
GM_{10}	Soil + FYM + *Rhizobium*	10.73	12.52	91.76	78.84	7.02	6.17	16.98
GM_{11}	Soil + Neemcake + *Trichoderma spp.* @ 2.5g	12.20	12.13	83.74	74.66	6.02	5.39	16.37
GM_{12}	Soil + Vermicompost + *Trichoderma spp.* @ 2.5g	11.87	12.26	85.77	75.67	6.34	5.64	16.52
GM_{13}	Soil + FYM + *Trichoderma spp.* @ 2.5g	12.27	12.00	83.18	72.74	6.95	5.18	15.93
GM_{14}	Soil + Neemcake + FYM	11.33	12.33	90.91	77.22	6.67	5.89	16.65
GM_{15}	Soil + Neemcake + Vermicompost + *Trichoderma spp.* @ 2.5g	10.43	12.96	93.91	79.63	8.03	6.96	17.33
GM_{16}	Soil + Neemcake + Vermicompost + *Rhizobium*	10.03	13.23	94.19	80.07	8.31	7.10	17.57
GM_{17}	Soil + FYM + Vermicompost	10.80	12.45	91.14	77.84	6.91	6.02	16.87
GM_{18}	Soil + Neemcake + Vermicompost + FYM+ *Rhizobium* + *Trichoderma spp.* @ 2.5g	10.00	13.32	94.54	81.03	8.94	7.27	17.80
S.Em±		**0.46**	**0.46**	**0.05**	**0.16**	**0.01**	**0.05**	**0.03**
CD (5%)		**1.33**	**1.33**	**0.13**	**0.47**	**0.03**	**0.13**	**0.09**

3.2 Shoot Parameters

3.2.1 Seedling height (cm)

Data from Table 1 revealed that the various treatments had significantly influenced on the seedling height in all the treatments except control or soil. However, maximum seedling height (8.94 cm) was observed with the application of treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). While, minimum seedling height (5.81 cm) was recorded under the treatment GM_1 (Soil).

3.2.2 Number of leaves per seedling

It was noticed from table that average number of leaves per plant was significantly influenced by the different propagation media and biofertilizers. Treatment GM_{18}(Soil +Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g) proved best among all the treatments. Maximum average number of leaves per plant (7.27) was registered under treatment GM_{18}. Whereas, lowest number of leaves per plant (4.00) were observed with the treatment GM_1(Soil).

3.2.3 Leaf area (cm^2)

Statistically analysed data regarding leaf area, presented in Table 1 revealed that various treatments had significant influenced on leaf area. Maximum leaf area (17.80 cm^2) was observed with treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). However, minimum leaf area (12.20 cm^2) was found under the treatment GM_1 (Soil).

3.2.4 Fresh weight of shoot (g)

It was found on the observing the data that the maximum fresh weight of shoot (4.34 g) was registered with the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium*+ *Trichoderma spp.* @ 2.5 g) and the minimum fresh weight of shoot (1.90 g) was recorded under the treatment GM_1 (Soil).

3.2.5 Dry weight of shoot (g)

The data pertaining to dry weight of shoot presented in Table 2 was significantly influenced against soil, when different propagation media and bio fertilizers were applied. It was seen that among all of the treatments the maximum dry weight of shoot (2.21 g) was observed with the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). On the other hand, minimum dry weight of shoot (0.87 g) was found with the treatment GM_1 (Soil).

3.3 Root Parameters

3.3.1 Length of roots (cm)

Statistically analyzed data presented in Table 2 indicated that the length of roots was significantly influenced by different propagation media and biofertilizers over soil. On observing, the maximum root length (7.21 cm) was registered with the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). Whereas the treatment GM_1 (Soil) recorded minimum length of roots (4.89 cm).

3.3.2 Diameter of roots (mm)

Data pertaining due to effect of propagation media and biofertilizers indicated that propagation media and biofertilizer had significantly influenced the diameter of roots. The maximum diameter of roots (1.05 mm) was found with the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). However, the minimum diameter of roots (0.80 mm) was observed with the treatment GM_1 (Soil).

3.3.3 Fresh weight of roots

Perusal of data presented in Table 2 indicated that the fresh weight of roots was significantly influenced by the different propagation media and biofertilizers over the soil. The maximum fresh weight of roots (1.04 g) was exhibited by the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). While, minimum fresh weight of roots (0.16 g) was found under the treatment GM_1 (Soil).

3.3.4 Dry weight of roots (g)

It was found on the observing the data that the maximum dry weight of root (0.44 g) was observed with the propagation media and biofertilizers treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). While, minimum dry weight of roots (0.02 g) was recorded with the treatment GM_1 (Soil).

Table 2. Effect of soil propagation media and bio-fertilizers on fresh weight of shoot (g), dry weight of shoot (g), length of roots (cm), diameter of roots (mm),fresh weight of roots (g), dry weight of roots (g) speed of germination, mean daily germination, peak value andgermination value in Aonla

Treatments	Fresh weight of shoot (g)	Dry weight of shoot (g)	Length of roots (cm)	Diameter of roots (mm)	Fresh weight of roots (g)	Dry weight of roots (g)	Speed of germination	Mean daily germination	Peak value	Germination value
GM_1	1.90	0.87	4.89	0.80	0.16	0.02	4.52	0.66	0.82	0.54
GM_2	1.96	0.98	5.26	0.84	0.21	0.04	4.90	1.14	0.91	1.03
GM_3	1.98	1.01	5.75	0.85	0.25	0.07	5.04	1.38	0.91	1.25
GM_4	1.93	0.96	5.04	0.83	0.19	0.03	4.74	0.93	0.88	0.82
GM_5	2.27	1.29	6.05	0.90	0.42	0.17	5.97	1.90	0.97	1.83
GM_6	2.13	1.18	5.94	0.89	0.37	0.13	5.73	1.83	0.95	1.73
GM_7	2.03	1.08	5.86	0.87	0.28	0.09	5.21	1.74	0.92	1.60
GM_8	3.62	1.83	6.88	1.01	0.81	0.39	6.95	2.72	1.19	3.22
GM_9	3.84	1.96	6.97	1.02	0.88	0.41	7.03	2.95	1.24	3.65
GM_{10}	3.49	1.71	6.76	0.99	0.79	0.32	6.87	2.63	1.17	3.08
GM_{11}	2.72	1.39	6.25	0.94	0.53	0.23	6.28	2.03	1.00	2.03
GM_{12}	2.97	1.41	6.41	0.96	0.57	0.27	6.57	2.19	1.03	2.24
GM_{13}	2.34	1.36	6.16	0.92	0.48	0.20	6.11	1.99	0.98	1.94
GM_{14}	3.07	1.47	6.50	0.97	0.69	0.29	6.64	2.24	1.09	2.43
GM_{15}	4.00	2.02	7.09	1.02	0.96	0.41	7.17	3.04	1.24	3.77
GM_{16}	4.13	2.12	7.12	1.03	1.02	0.43	7.37	3.42	1.32	4.51
GM_{17}	3.27	1.59	6.63	0.99	0.72	0.30	6.72	2.57	1.18	3.03
GM_{18}	4.34	2.21	7.21	1.05	1.04	0.44	7.56	3.53	1.33	4.68
S.Em±	**0.01**	**0.01**	**0.02**	**0.01**	**0.004**	**0.003**	**0.01**	**0.01**	**0.05**	**0.12**
CD (5%)	**0.02**	**0.02**	**0.04**	**0.02**	**0.01**	**0.01**	**0.02**	**0.02**	**0.13**	**0.35**

3.4 Seedling Vigour Characters

3.4.1 Speed of germination

Speed of germination was significantly influenced by the propagation media and biofertilizers over soil. Data showed that the maximum speed of germination (7.56) recorded under the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). On the other hand, minimum speed of germination (4.52) was reported by the treatment GM_1 (Soil).

3.4.2 Mean daily germination

Data revealed that the mean daily germination was significantly influenced by the propagation media and biofertilizers over the control or soil. The maximum mean daily germination (3.53) was registered with the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). Minimum mean daily germination (0.66) was found under the treatment GM_1 (Soil).

3.4.3 Peak value

Significant influence on peak value was observed due to the propagation media and biofertilizers, data regarding the peak value. It is clear from the table that the maximum peak value (1.33) was exhibit in the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g). Whereas, the treatment GM_1 (Soil) reported minimum (0.82) peak value.

3.4.4 Germination value

The data indicated that the propagation media and biofertilizers have a significant influence on germination value. The treatment GM_{18}(Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g) recorded the maximum germination value (4.68). Other than these treatments, the treatment GM_1(Soil) registered minimum germination value (0.54).

4. DISCUSSION

4.1 Seed Germination Parameters

4.1.1 Days taken to seed germination

The minimum days taken to germination (10.00 days) was seen under treatment GM_{18} (Soil + Neemcake + vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g), while, maximum days taken to germination (13.33 days) were found with GM_1 (Soil). “It might be due to external application might have boosted the growth by increasing cell multiplication and cell elongation, resulting in rapid plant growth. The rapid and early germination might have helped in producing vigorous growth of seedlings during subsequent period of growth” Anjanawe et al., [12]. Another reason that media containing organic manures possess organic acid within them. Therefore, more available moisture and some acids may have helped in minimum days to germination and better germination percentage. Similar results were reported by Maiti et al. [13] in jackfruit, Zhao et al. [14] in papaya and Prasana et al. [15] in mango.

4.1.2 Number of seedling sprouted

“The maximum number of seedling sprouted (13.32) was observed with GM_{18}, while, minimum number of seedling sprouted (11.04) were found with GM_1. This might be due to favourable medium for better growth of the seedling, particularly for good development of root system” [16]. These results are in close agreement with Shamet *et al*. [17].

4.1.3 Germination percentage

The maximum germination percentage (94.54 %) was observed with treatment GM_{18}, while, minimum germination percentage (74.70 %) was found with treatment GM_1. It might be due to the reason that media containing organic manures possess organic acid within them. Therefore, more available moisture and some acids may have helped in minimum days to germination and better germination percentage Mishra et al. [18] in papaya. Similar results were reported by Prasana et al. [15] in mango. Another reason might be that the improvement in soil texture, porosity, water holding capacity, activity of soil microflora and fauna which helps in maintaining soil temperature and improving soil health nutrients of the medium, [19] in papaya. Same results reported by Hartmann and Kester [20]. Biofertilizers helps in the synthesis of beneficial hormones and growth factors that will leads to the increased cell division and multiplication of cell also increases the assimilation and accumulation of food materials (Raman, 2012) in apple. Similar results were observed in shea tree by Abdullahi et al. [21], Verma et al. [22] in dragon fruit and in sweet orange by Rana et al. [23].

4.1.4 Survival percent

The maximum survival percent (81.03 %) was observed with GM_{18}, while, minimum survival percent (64.66 %) was found with GM_1. It might be due the reason that it has relatively high content of humus-like compounds, active micro organisms, enzymes as well as physical and nutritional condition which increased the physiological activities of plant Hota et al. [24] in jamun. These findings are supported by Shamet et al. [17], Prasana et al. [15] and Barela et al. [3] in Moringa.

4.2 Shoot Parameters

4.2.1 Seedling height

The maximum seedling height (4.20 cm) was observed with treatment GM_{18}, while, minimum seedling height (2.00 cm) was found with treatment GM_1 (Soil). This might be attributed to general improvement in the physical and chemical properties of the rooting medium [18]. Similar results were obtained by Shamet et al., [17] in Chilgoza pine, and Nelson et al. [25] in arnotta plant (*Bixa orellana*). Another reason may be that the improvement in soil texture, porosity, water holding capacity, activity of soil microflora and fauna which helps in maintaining soil temperature and improving soil health nutrients of the medium, [19] in papaya. Same results reported by Hartmann and Kester [20].

4.2.2 Number of leaves per seedling

The maximum number of leaves per seedling (7.27) was observed with treatment GM_{18}, while, minimum number of leaves per seedling (4.00) was found with treatment GM_1. It might be due to better nutrient availability leading to higher production of photo synthetically functional leaves due to growing media [26]. Similar results were reported by Anjanawe et al. [12] in papaya and Parasana et al. [15] in mango. Another reason might be that adequate amount of farmyard manure added to the soil with biofertilizers, it improved biofertilizer efficiency and ultimately nutrient status of the soil, [27]. It might have decomposed and released nutrients that helps in production of more number of leaves, [1]. Similar observations on number of leaves were observed by Devachandra et al., [28] in jamun, Muralidhara et al. [29], Mishra et al. [18].

4.2.3 Leaf area

The maximum leaf area (17.80 cm^2) was observed with GM_{18}, while, minimum number of leaves per shoot (12.20 cm^2) was found with GM_1. Manure provides adequate nutrients and enhances both the physical and the water holding capacity [30 and 31]. Similar result was also reported by Supriyanto et al. [32] in orange.

4.2.4 Fresh weight of shoot

The maximum fresh weight of shoot (4.34 g) was observed with GM_{18}, while, minimum fresh weight of shoot (1.90 g) was found with GM_1 (Soil). It might be due to some plant growth promoters in worm casts which increase physiological activities, essential for cell division, cell enlargement or both [24]. The findings are supported by Roy and Shrivastava [33].

4.2.5 Dry weight of shoot

The maximum dry weight of shoot (2.21 g) was observed with GM_{18}, while, minimum dry weight of shoot (0.87 g) was found with GM_1 (Soil). It might be due to improved soil fertility, thereby rendering more availability of nutrients required for plant growth and development (Vasantha et al., 2014). The findings are supported by Ratan and Reddy [34] in annona, Hota et al. [24] in jamun.

4.3 Root Parameters

“The maximum length of roots (7.21 cm), diameter of roots (1.05 mm) fresh weight of roots (1.04 g) and dry weight of root (0.44 g) was observed with GM_{18} (Soil + Neemcake + vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g), while, minimum length of roots (4.89 cm), diameter of roots (0.80 mm), fresh weight of root (0.16 g) and dry weight of root (0.02 g) was found with GM_1 (Soil). This might be due to favourable medium for better growth of the seedling, particularly for good development of root system” [16]. These results are in close agreement with Shamet et al. [17] and Mishra et al. (2017) in papaya.

4.4 Seedling Vigour Parameters

“The maximum speed of germination (7.56), mean daily germination (3.53), peak value (1.33) and germination value (4.68) was observed with treatment GM_{18} (Soil + Neemcake + vermicompost + FYM + *Rhizobium* +

Trichoderma spp. @ 2.5 g), while, minimum speed of germination (4.52), mean daily germination (0.66), peak value (0.82) and germination value (0.54) was found with treatment GM_1 (Soil). Since organic matter acts as glue for soil aggregation which improve permeability and air flow in polybags, also improve nutrient availability and improve phosphorus absorption" (Karama and Manwan,1990). "All these factors are favourable for seed germination and ultimate by increase seed germination percent, speed of emergence, seed vigour, germination index, germination value and reduce imbibitions period" (Bhardwaj, 2014) [35-40].

5. CONCLUSION

On the basis of results obtained in present investigation it is concluded that treatment T_7 (@ 75 kg P_2O_5/ha + PSB @ 5 g/kg seed) was found to be the best. While, the treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g) was found to be the best for seed germination characters i.e., days taken to seed germination, number of seedling sprouted, length of shoot, fresh & dry weight of shoot, number of leaves per plant, leaf area, success percentage of seed germination, survival percent, length of roots, diameter of roots, fresh weight and dry weight of roots.

Various seedling vigour characters like speed of germination, mean daily germination, peak value, germination value, germination percentage, seedling height and number of leaves per seedlings were also found best/maximum with treatment GM_{18} (Soil + Neemcake + Vermicompost + FYM + *Rhizobium* + *Trichoderma spp.* @ 2.5 g).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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