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Research Article

Effect of Growing Media on Seed Germination and Seedling Growth of Chili (*Capsicum Annuum* L.)

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ABSTRACT

Suitable growing media is considered a basic requirement to get the maximum germination and growth. So, the present investigation was carried out at Mominpur Farmers Hub (name of model), Rangpur Sadar Upazila during February-March, 2023 to investigate the effect of growing media on germination percentage, germination emergence percentage, shoot length, shoot fresh weight, root length, root fresh weight, leaf number, shoot length vigor index, root shoot ratio of chili under open field condition. The experiment was sequenced according to Completely Randomized Design in three replicates. Five different growing media namely soil + sand, cocopeat, soil + sand + cocopeat, vermicompost + cocopeat, and vermicompost + soil + sand was used in the experiment. The results obtained from this study showed that the maximum germination percentage (94%), shoot length (9.62 cm), shoot fresh weight (7.16 g), root length (3.09 cm), root fresh weight (1.93 g), leaf number (7.02) and shoot length vigor index (1194.74%) were recorded when the seed was growing in the cocopeat. The findings of this study recommend to use of cocopeat as a growth media for raising nurseries by farmers as it had a significant positive effect on seed germination and plant growth parameters of seedlings that lead to increased production of chili.

Keywords: Chili, Germination percentage, Growth media, Cocopeat, Vermicompost

Introduction

Chili (*Capsicum annuum* L.) is an important vegetable as well as spice crop, used worldwide for domestic and commercial purposes (Khan *et al.,* 2012). Chili are the principal crops of the Solanaceae family having diploid species with 2n=2x=24 chromosomes, grown in sub-tropics and tropics. Chili is grown over an area of 9.68

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thousand hectares with a production of 14.94 thousand ton's and an average yield of 1.54 ton ha^{-1} during 2018-19 (BBS, 2020). This species is known to be a vegetable that low in calories and high in potassium, vitamin A, and vitamin C content (Chew, 2018). Furthermore, green chili is proven to be a source of metabolites with an antioxidant activity which makes it potential to treat disease against cancer, precluding gastric ulcers and activating the immune system (Sun *et al*., 2007). The genus *Capsicum* spp. includes around 30 species, of which *C. annuum, C. chinense* and *C. frutescens* are the most widely cultivated (Moquammel *et al*., 2016). The species *C. annuum* L. is the widely distributed and important in the world due to its different uses and its adaptation (Toledo-Aguilar *et al*., 2016).

Growing media have an important effect on the growth of seedlings along with the climatic conditions. In vegetable production, the seedling stage of the plant life cycle is an important stage that is effective for growth and development. Production of healthy and vigorous chili seedlings is the key factor in successful commercial chili production and yield of quality chili fruits. The seedling production using traditional methods causes stress in plants. There are many kinds of materials that are used for seed-sowing medium. The main properties wanted in growing media are that they can be found easily, cheaply and abundantly, and it was also wanted that they are rich in nutrients, and have high water holding capacity and good aeration, and must also be easy to transport. Growing media used in the production of seedlings in nurseries include organic materials such as peat, tree bark, compost, coconut fiber, vermicompost, rice husk ash or inorganic materials such as perlite or vermiculite (Grunert *et al*., 2008; Nair *et al*., 2011). These growing substrates consist of either a single component or mixtures which support plants by providing water, air and nutrients (Yilmaz *et al*., 2014; Oagile *et al*., 2016). However, different growing media vary greatly in particle size, pH, aeration and ability to hold water and nutrients (Oagile *et al*., 2016).

Cocopeat is an organic material made from coconut peel. The long fibers of coconut are used in the manufacturing of brushes, spinning, car seats and mattress stuffing, while, short fibers (2 mm and less) and the dust are further cut, crushed and washed to produce a new product suitable to use as a planting medium. Prior studies showed that cocopeat has been used as an environment friendly substitute for peat in soilless growing media for containerized plants in recent years (Evans *et al*., 1996; Noguera *et al.,* 2000; Kumarasinghe *et al.,* 2015). Cocopeat is considered a good growing medium component with acceptable pH, electrical conductivity and other chemical attributes (Evans *et al.,* 1996; Abad *et al.,* 2002; Awang *et al.,* 2009). As a growing medium, it can be used singly or as a component of a medium to raise different plant species with acceptable quality (Blom, 1999; De Kreij and Leeuven, 2001; Treder, 2008). Yahya *et al*. (2009) stated that cocoa peat is an agricultural by-product obtained after the extraction of fiber from the coconut husk. As a growing medium, cocoa peat can be used to produce several crop species with acceptable quality in the tropics. Cocoa peat is considered a good growing media component with acceptable

pH, electrical conductivity and other chemical attributes.

Vermicomposting is a bio-oxidative mesophilic process of transforming organic waste into vermicompost where detritivorous earthworm species interact with microorganisms, intensely affect the breakdown processes, accelerate the steadiness of organic matter, and improve its physical, chemical, and biological properties (Dominguez and Gómez-Brandon, 2013). Vermicompost is widely used as a biofertilizer, soil activator, fertility booster, and soil conditioner because it contains plant nutrients, enzymes, vitamins, growth hormones, and beneficial microbes such as nitrogen-fixing, phosphate-solubilizing, denitrifying, and decomposing bacteria (Jemal and Abebe, 2020; Murunga *et al*., 2020). The application of vermicompost produced by biodegradable waste could be one of the most economical and attractive methods of solving problems like waste disposal and the requirement to increase the organic matter content of soil.

Keeping in view the influence of media in germination and seedling growth of chili, the present investigation was carried out to study the effect of different media viz. sand, vermicompost and cocopeat on the germination, seedling growth and vigour of chili seedlings. The specific objectives are as follows: i) to study the effects of different growing media on germination percentage of chili seeds and ii) to assess the effects of various growing media on different seedling attributes of chili.

Materials and Methods

Experimental Site, Design, Treatments and Cultural Practices

This experiment was carried out at Mominpur farmers hub name of farmers model, Rangpur sadar (90°38′N, 24°95′E), Rangpur, Bangladesh during February to March, 2023. Chili (*Capsicum* annuum L.) variety "Radhika" was used for this study. Seeds were obtained from ACI Ptv. Ltd., Rangpur. Chili seeds were sown singly in 100 Plastic Styrofoam seedling trays filled with the different commercial growing media (treatments) viz., T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Cocopeat and vermicompost were purchased from GBK Enterprise Ltd. Parbortipur, Dinajpur (Fig. 1). The experiment was laid out in a complete randomized design (CRD) with the three growing media treatments replicated three times. Seedlings were irrigated in the morning and afternoon until the termination of the experiment.

Data Collection and Analysis

Data collected comprised of seedling emergence, growth and development parameters (Shoot length, leaf number, shoot fresh weight, root length and root fresh weight). Seedling emergence was measured cumulatively on a daily basis by counting any emerging seedlings from the 100 plugs per tray until a constant reading. Ten seedlings in the middle of each tray were tagged for growth and development parameters measurements which commenced after the development of true leaves

and continued weekly until the termination of the experiment (approximately seven weeks duration). Shoot height was measured from the base of plant to the shoot tip and leaf number was determined by counting fully opened leaves. At the end of the experiment, all ten tagged plants were harvested and placed in brown paper bags for shoot fresh weight, root length and fresh weight determination. Shoot fresh weight was determined immediately after harvest using an electronic balance.

Seed Germination Characteristics

Germination percentage (%) was calculated using the following formula (Scott *et al.,* 1984):

$$\text{Germination (\%)} = \frac{\text{Total numbers of germinated seeds}}{\text{Total seed placed for germination}} \times 100$$

The vigor index was calculated using the following formula (Abdul-Baki and Anderson, 1973): Shoot length vigor index = Germination (%) × Plumule length + Radicle length,

Statistical Analysis

Mean values were taken from measurements of three replicates and standard deviation (SD) of the means was calculated. The collected data was analyzed the statistically using statistics10 software.

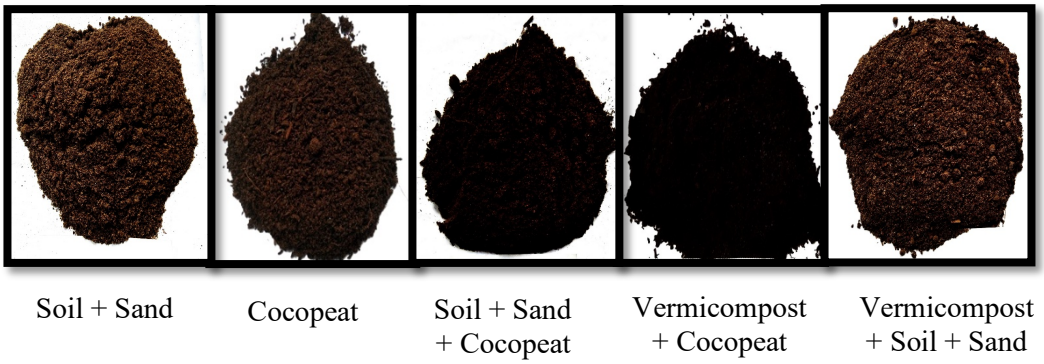

Plate 1. Pictorial view of different types of growing media

Results and Discussion

Effects of Different Growing Media on Germination (%) and Seedling Emergence of Chili

The germination percentage of chili seeds was significantly affected by the growth medium (Figure 1). The significantly higher germination percentage of chili was found to be 94% in T_1 (cocopeat), while the lowest (78%) germination was recorded

in T_0 [soil + sand (1:1)]. Germination percentages varied from 86-89% in different growing media. The lowest germination in T_0 [soil + sand (1:1)] may be due to low water retention capacity and low nutrient availability (Meena et al., 2017). Growing media significantly increase seed germination, seedling emergence and growth of seedlings in a nursery because these media serve as reservoirs of moisture and plant nutrients. These results were supported by Utteker et al. (2021) who reported that media containing cocopeat resulted in the highest germination (%) while the lowest germination (%) was observed in media containing soil + sand (1:1) in mango seedlings. Cocopeat is considered the best growing medium component with acceptable pH, electrical conductivity and other chemical attributes (Evans *et al*., 1996, Abad *et al*., 2002, Awang *et al*., 2009).

The percent seedling emergence showed that emerged showed after fourteen days of seed sowing (Figure 2). There were no significant differences in seedling emergence among the treatments except T_0 treatment. The higher seedling emergence observed in the T_1 (cocopeat), T_2 (soil + sand + cocopeat) and T_4 (vermicompost + soil + sand) up to 20 days could also probably be attributed to the fact that the growing media possess good physical and chemical properties that enhanced seedling's emergence. Seed germination is influenced by different factors that include the type of growing media and environmental factors such as oxygen, nutrient and water availability, temperature and light (Baiyeri and Mbah, 2006). This result is consistent with the results of Bhandari and Kharal, (2019) they reported that the maximum speed of germination (1.964) was found in coco peat. The least speed of germination (0.974) was found in control (soil treatment).

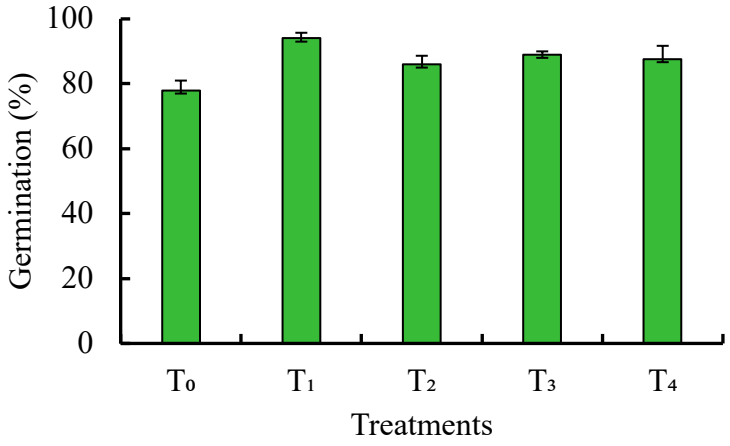

Fig. 1. Effect of different growing media on germination (%) of chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD and bars indicate SD.

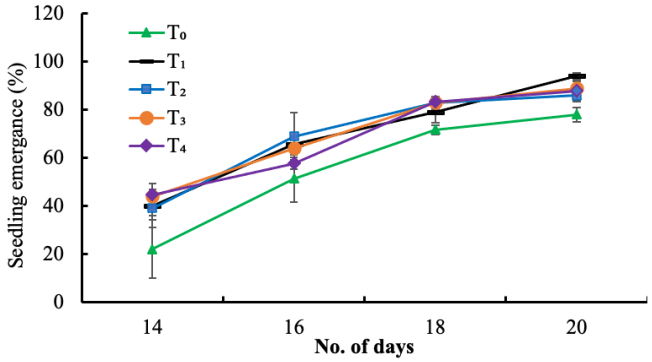

Fig. 2. Effects of different growing media on seedling emergence (%) of chili at different days after sowing. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of Different Growing Media on Shoot Length of Chili

Figure 3 shows that the shoot length varied significantly with the growing media at different days after sowing (DAS) i.e., at 20, 35 and 50 DAS. The growth of plants was increased (6.03 cm) significantly for the 35 DAS compared to the 20 DAS. The treatment T_1 (cocopeat) showed the highest performance (9.62 cm) among others until the 50 DAS. However, treatment T_3 (vermicompost + cocopeat) showed the lowest performance (5.61cm) compared to other treatments. According to Haring *et al*., 2021 stated the bara variety of chili with the planting medium of cocopeat had the highest plant height (81.50 cm). These outcomes are match with the results of Atif *et al.* (2016) found that equal proportion of compost, peat and traditional practicing media also enhanced tomato shoot length. After 30 days aged seedling higher shoot length were observed in coir pith media (Vivek and Duraisamy, 2017).

Effects of Different Growing Media on Shoot Fresh Weight of Chili

The significantly highest shoot fresh weight (7.16 g) was obtained by the treatment T_1 (cocopeat) compared with all other growing media (Figure 4). While the lowest shoot fresh weight (2.1 g) was obtained from the T_0 (soil + sand) treatment. No significant differences were observed in the shoot fresh weight among treatments T_2 [soil + sand + cocopeat (3.23 g)], T_3 [vermicompost + cocopeat (2.9 g)] and T_4 [vermicompost + soil + sand (2.66 g)], but was significantly different from T_0 (soil + sand). A similar result was reported by Cahyo, (2019) where fresh weight of Rubber plants increased with 100% cocopeat compared to control (soil). The higher N, P and K content in the cocopeat had possibly contributed to the better growth of the rubber trees where media containing cocopeat.

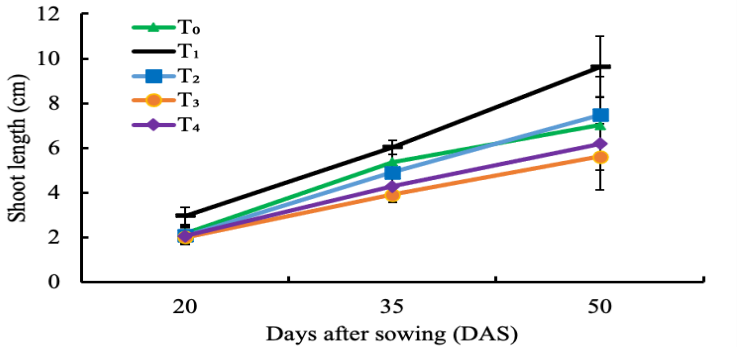

Fig. 3. Effects of different growing media on shoot height of chili at different days after sowing. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

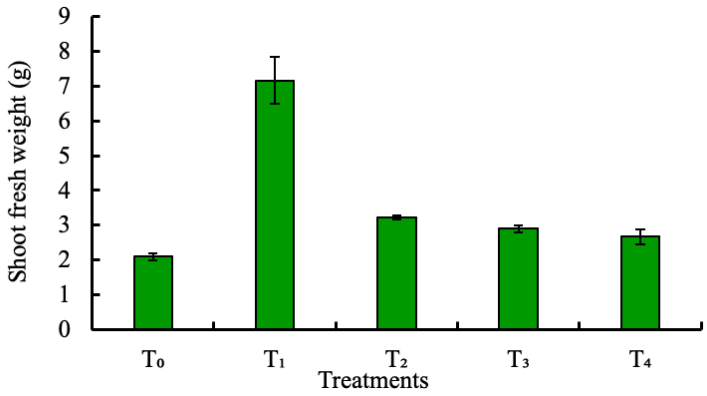

Fig. 4. Effect of different growing media on shoot fresh weight of Chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of Different Growing Media on Root Length of Chili

In figure 5 shows that the treatment of T_1 (cocopeat media) had the highest root length (3.09 cm), significantly different from the root length of other treatments, T_0 [soil + sand (1.58 cm)], T_3 [vermicompost + cocopeat (1.97 cm)] and T_4 [vermicompost + soil + sand (2.12 cm)]. Growing media, treatment T_2 (soil + sand + cocopeat) had the lowest root length (1.42 cm). These results suggested that the cocopeat media is more suitable than other media because of more physical properties and enhanced nutrient level. Cocopeat is a better growing media serve as a storage for nutrients and water for the plant, allow diffusion of oxygen in root zone and external atmosphere of root substrate which provide adequate support to the plant

(Abad *et al*., 2002). These results matched with the finding of Unal (2013) reported that the best outcomes regarding tomato seedling root length in M4 (peat-stable manure-perlite) and M5 (peat-sand-NPK) media. Moreover, Kotur, (2014) observed that the highly porous and favourably moist cocopeat, in comparison to soil, did not favour proper root growth in most cases except in capsicum in terms of overall vigour, and in pigeon pea, for length of tap root.

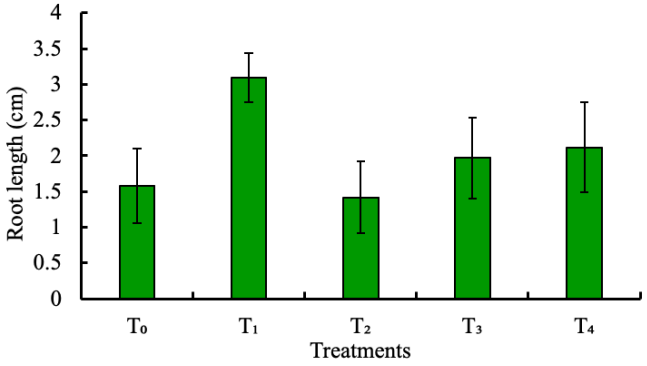

Fig. 5. Effect of different growing media on root length of Chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effect of Different Growing Media on Root Fresh Weight of Chili

The total root fresh weight of chili was significantly highest (1.93 g) by the treatment of T_1 (cocopeat). The treatment of T_4 (vermicompost + soil + sand) produced the lowest (0.8 g) total root fresh weight of chili. However, there was no significant difference of T_0 (0.97 g), T_2 (1.00 g), T_3 (0.866 g) and T_4 (0.8 g) treatment growing media (Figure 6). This result is consistent with Cahyo (2019) and found that the good root growth of rubber on cocopeat can be seen from the gradual increment of root fresh weight and volume with increasing proportion of cocopeat.

Effects of Different Growing Media on Leaf Number of Chili

The leaf is the major organ involved in light perception and the conversion of solar energy into organic carbon (Malinowsk, 2013, Du *et al*., 2019). The leaf number is a very important character for plant growth and development. The figure 7 showed the changes of mean in number of leaves for growing media over time. Plant using the medium of cocopeat (T_1) showed the highest mean number of leaves at 20DAS (2.00), 35DAS (5.3) and 50DAS (6.9). Meanwhile, planting media vermicompost + cocopeat (T_3) still the lowest mean number of leaves (2.00, 4.2 and 4.9 at 20DAS, 35DAS and 50DAS, respectively) were showed over the time planting. These consequences are similar with the conclusions of Kumarasinghe *et al*. (2015) found that cocopeat media is good to increase leaf number per tomato seedling. Higher number of leaves was produced due to nutritional contribution of the media.

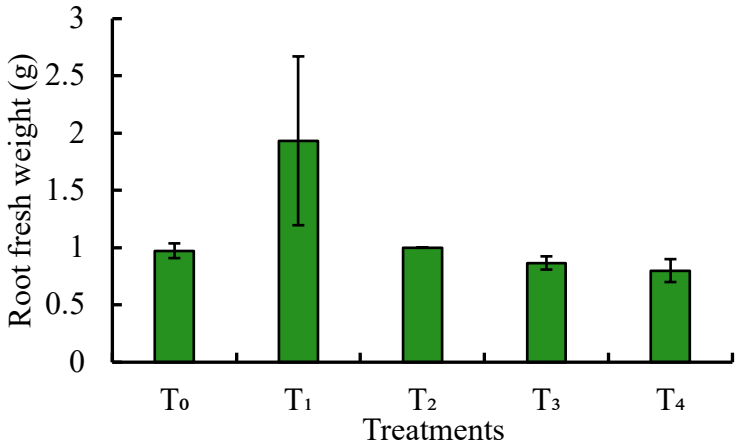

Fig. 6. Effect of different growing media on root fresh weight of chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

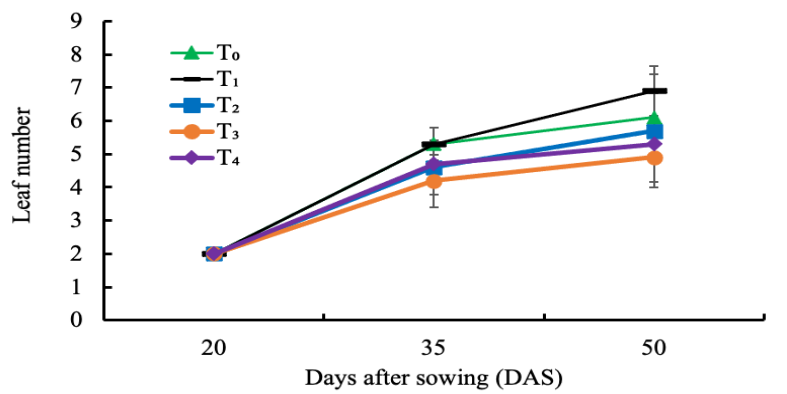

Fig. 7. Effects of different growing media on leaf number of chili at different days after sowing. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat, and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of Different Growing Media on Shoot Length Vigor Index of Chili

Copeland and McDonald, (1995) reported that vigor of seedlings relates with their ability upon germination to grow rapidly and well. Among the growing medium, higher shoot length vigor index was observed in T_1 [cocopeat (1194.74)], while lower in T_3 [vermicompost + cocopeat (664.83)] treatment. Moreover, there was no significant difference in shoot length vigor index of T_2 [soil + sand + cocopeat (765.4)], T_0 [soil + sand (670.82)], T_3 [vermicompost + cocopeat (664.83)] and T_4 [vermicompost + soil + sand (728.57)] treatments (Figure 8). It seems that good physical and biological conditions in cocopeat had positive effect on root

development, which is helpful in increased seedling length vigor index of chili.

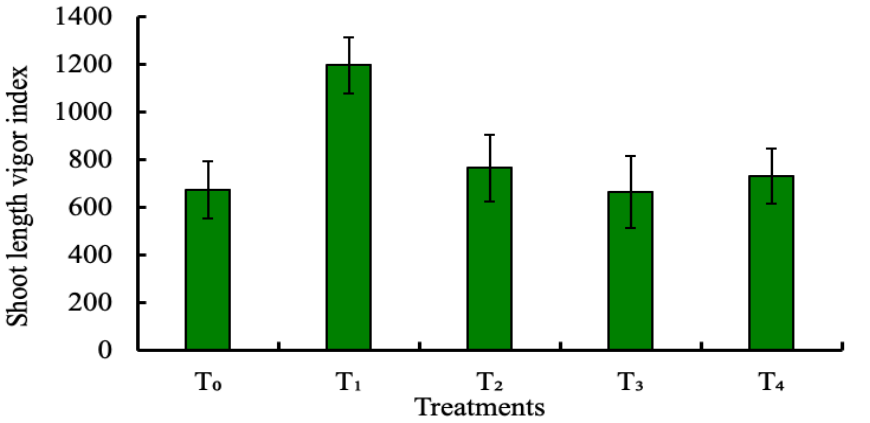

Fig. 8. Effect of different growing media on seedling length vigor index of chili. T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat and T_4 = vermicompost + soil + sand. Data are mean ± SD (standard deviation) and bars indicate SD.

Effects of Different Growing Media on Root and Shoot Ratio of Chili

The root and shoot length ratio were affected by growing media (Table 1). The root and shoot growth were influenced by different growing media to which the maximum root and shoot ratio (0.377) was recorded in the treatment T_3 and it was at par with T_1 and T_4. However, the minimum root and shoot ratio (0.199) was registered in T_2 (soil + sand + cocopeat). The better root and shoot ratio might be due to better aeration and water holding capacity of the media, which invigorates improved physiological activities of the plant and thus, helps in obtaining maximum root and shoot dry mass, which further results in higher root to shoot ratio. These findings are in close relation with earlier findings of Dhakar *et al*. (2016) in papaya.

Table 1. Effect of the different growing media on root and shoot length ratio of chili

Treatments	Root and shoot length ratio
T_0	0.226±0.073
T_1	0.329±0.077
T_2	0.199±0.086
T_3	0.377±0.167
T_4	0.338±0.125

Note: T_0 = soil + sand, T_1 = cocopeat, T_2 = soil + sand + cocopeat, T_3 = vermicompost + cocopeat and T_4 = vermicompost + soil + sand.

Conclusion

The presented results showed that cocopeat is the best due to suitable physical, chemical and biological properties could be used best media to grow. Considering the results, it may be concluded that sowing seeds of chili in growing media cocopeat gave higher parameter of germination, and enhanced growth of seedlings as compared to media without cocopeat. Based on the findings of this study cocopeat growing media may be advised for raising chili nurseries by farmers as it has a significant positive effect on plant growth parameters.

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References

Abad, M., Noguera, P., Puchades, R., Maquieira, A. and Noguera, V. (2002). Physico-chemical and chemical properties of some coconut dusts for use as a peat substitute for containerized ornamental plants. *Bioresources Technology*, 82, 241-245.

Abdul-Baki, A.A. and Anderson, J.D. (1973). Vigor determination in soybean seed by multiple criteria. *Crop science*, 13, 630-633.

Atif, M.J., Jellani, G., Malik, M.H.A., Saleem, N., Ullah, H., Khanand, M.Z. and Ikram. S. (2016). Different growth media effect the germination and growth of tomato seedlings. *Science Technology Development,* 35(3): 123-127.

Awang, B., Shaharom, A. S., Mohammad, B., Selamat, A., Ayub, M., Ullah, J. and A. Muhammad, A., (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of Celosia cristata. *American Journal of Agricultural and Biological Science*, 4, 63-71.

Baiyeri, K.P. and Mbah, B.N. (2006). Effects of soilless and soil-based nursery media on seedling emergence, growth and response to water stress of African breadfruit (Treculia africana Decne). *African Journal Biotechnology,* 5(15):1405-1410.

BBS (2020). Yearbook of Agricultural Statistics of Bangladesh-2019. Bangladesh Bureau of Statistics, Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Bhandari, A. and and Kharal, B. (2019). Effect of different growth media on seed vigor characteristics of tomato (*Solanum lycopersicum* L.) cv. Gaurav-555 in Agrhakhanchi, Nepal. *International Journal of Scientific & Engineering Research,* 10(9): 511-522.

Blom, T.J. (1999). Coco coir versus granulated roockwool and 'arching' versus traditional harvesting of roses in a recirculating system. *Acta Horticulture*, 481, 503-507.

Cahyo, A.N., Sahuri, Nugraha, I.S. and Ardika, R. (2019). Cocopeat as Soil Substitute Media for Rubber (*Hevea brasiliensis Müll*. Arg.) Planting Material. *Journal of Tropical Crop Science*, 6(1): 24-29.

Chew, B.H. (2018). Grow your own vegetables. Kuala Lumpur, Malaysia: MPH Group Publishing Sdn Bhd.

Copeland, L. O. and McDonald, M. B. (1995). Seed vigour and vigour tests. In: Principles of seed science and technology (3rd edn.). Chapman and Hall, New York. Pp. 153-180.

De Kreij, C. and Leeuven, G.J.L. (2001). Growth of pot plants in treated coir dust as compared to peat. *Communications Soil Science Plant Analysis*, 32(1314), 2255-2265.

Dhakar, S. S., Kaushik, R. A. and Sarolia, D. K., (2016). Influence of growing media and containers on germination & seedling growth of papaya (*Carica papaya* L.) cv. Pusa Nanha. *Green Farming*, 7, 451-454.

Domínguez, J. and Gómez-Brandón, M. (2013). The influence of earthworms on nutrient dynamics during the process of vermicomposting. *Waste Management Research*, 31, 859-868.

Du, B., Liu, L., Wang, Q., Sun, G., Ren, X., Li, C. and Sun, D. (2019). Identification of QTL underlying the leaf length and area of different leaves in barley. *Scientific Reports*, 9, 4431.

Evans, M. R., Konduru, S. and Stamps, R. H. (1996). Source variation in physical and chemical properties of coconut coir dust. *Horticultural Science*, 31, 965-967.

Grunert, O., Perneel M. and Vandaele, S. (2008). Peat-based organic grow bags as a solution to the mineral wool water problem. *Mires and Peat*, 3, 1-5.

Haring, F., Amin, A. R., Rabbi, K., Kaimuddin, Farid B. D. R. M., Widiayani, N., Novaty, E., Dungga, F. U. and Sahur, A. (2021). Test on Cayenne chili (*Capsicum frutescens* L.) varieties on different growing media bioponically. IOP Conf. Series: *Earth and Environmental Science*, 807, 042056.

Jemal, K. and Abebe, A. (2020). Effect of different bedding materials and waste feeds on vermicompost production and local earthworm performance in Wondo Genet Ethiopia. *Asian Journal of Plant Science and Research*, 10, 13-18.

Khan, A. L., Shinwar, Z. K., Kim, Y., Waqas, M., Hamayun, M. K. and Lee, I. (2012). Role of endophyte Chaetomium globosum lk4 in growth of *Capsicum annuum* by production of gibberellins and indole acetic acid. *Pakistan Journal of Bot*any, 44, 1601-1607.

Kotur, S. C., (2014). Influence of fermented cocopeat on seedling vigour in some vegetables, marigold and pigeon pea. *Journal of Horticultural Science*, 9, 191-195.

Kumarasinghe, H.K.M.S., Subasinghe, S. and Ransimala, D. (2015). Effect of cocopeat particle size for the optimum growth of nursery plant of greenhouse vegetables. *Tropical Agriculture Research Extension,* 18(1), 51-57.

Malinowski, R. (2013). Understanding of Leaf Development-The Science of Complexity. *Plants*, 2, 396-415.

Meena, S. K. and Meena, V. S. (2017). Importance of Soil Microbes in Nutrient Use Efficiency and Sustainable Food Production. In book: Agriculturally Important Microbes for Sustainable Agriculture, .3-23.

Moquammel, S. K. H. et al. (2016). Karyological studies of two hot chili pepper cultivars

from two different geographical regions of India: Bhut jolokia, *Capsicum chinense* Jacq. and Bullet Lanka, *Capsicum annuum* L. *The Nucleus*, 59, 227-233.

Murunga, S. I., Wafula, E. N. and Sang, J. (2020). The use of freshwater sapropel in agricultural production: a new frontier in Kenya. *Advanced Agriculture*, 2020, 8895667.

Nair, A., Ngouajio, M. and Biernbaum, J. (2011). Alfalfa-based organic amendment in peat compost growing medium for organic tomato transplant production. *Horticultural Science*, 46, 253-259.

Noguera, P., Abad, M., Puchades, R., Noguera, V. and Martinez, J. (2000). Physical and chemical properties of coir waste and their relation to plant growth. *Acta Horticulture*, 450, 365-374.

Oagile, O., Ramalekane, O., Mojeremane, W., Matsuane, C., Legwaila G. M. and Mathowa, T. (2016). Growth and development response of Kale (Brassica oleracea var. Acephala L.) seedlings to different commercial growing media. *International Journal of Plant and Soil Science*, 12, 1-7.

Scott, S., Jones, R. and Williams, W. (1984). Review of data analysis methods for seed germination. *Crop Science*, 24, 1192-1199.

Sun, T., Xu, Z., Wu, C.-T. and Janes, M. (2007). Antioxidant Activities of Different Colored Sweet Bell Peppers (*Capsicum annuum* L.). Journal of Food Science, 72(2), S98-102.

Toledo Aguilar, R. et al. (2016). Morphological diversity of native population's poblano pepper. *Revista Mexicana de Ciencias Agrícolas*, 7, 1005-101.

Treder, J. (2008). The effects of cocopeat and fertilization on the growth and flowering of oriental lily 'star gazer'. *Journal Fruit Ornamental Plant Research*, 16, 361-370.

Unal, M. (2013). Effect of organic media on growth of vegetables seedlings. *Pakistan Journal Agriculture Science*, 50(3), 517-522.

Uttekar. (2021) Studies on production of quality seedlings for grafting and acclimatization of chili (*capsicum annum* L.) grafts. M. Sc. Thesis submitted to Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (Unpublished).

Vivek, P. and Duraisamy, V.M. (2017). Study of growth parameters and germination on tomato seedlings with different growth media. *International Journal Agriculture Science Research*, 7(3), 461-470.

Yahya, W., Shaharom, A. S., Mohamad, R. B. and Selama, A. (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of Celosia cristata. *American Journal of Agricultural and Biological Science*, 4, 63-71.

Yilmaz, E., Sonmez, I. and Demir, H. (2014). Effects of zeolite on seedling quality and nutrient contents of cucumber plant (*Cucumis sativus* L. cv. Mostar F1) grown in different mixtures of growing media. *Communications in Soil Science and Plant Analysis*, 45, 2767-2777.