Greening agriculture with cocopeat: Paving the way for sustainable crop production

Abstract

Soil degradation, a worldwide problem, can be considered a global pandemic. One of the mitigation measures involves integrated nutrient management and organic amendments involving the use of locally available organic resources and external fertilizers. Cocopeat is one such organic material that is a secondary product obtained from coconut processing industries in abundant amounts. Cocopeat is also known as coir pith. Several studies proposed that cocopeat can be used as either soilless growing media with few organic amendments or as soil amelioration that may improve the physical, chemical, and biological properties of soil, and it is a source of readily available plant nutrients. The study was conducted from mid-April to mid-June over a period of 60 days. The soil was amended with varied concentrations of cocopeat (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 100%), and appropriate fertigation was done. The present study evaluates the effect of cocopeat amended soil on soil's physical and chemical properties and plant growth of *Clitoria ternatea* seedlings.

The results demonstrate that increasing cocopeat concentration improved physicochemical parameters of growing media compared to control treatment, i.e., 100% soil resulting in increased availability of nutrients to plants and stimulating plant growth. Also, cocopeat incorporation into soil improved the morphological parameters of plants grown in them as shown by enhanced seedlings height and dry weight compared to control. But application of 100% cocopeat showed growth inhibition in *Clitoria ternatea* seedlings.

Keywords: *Clitoria ternatea, Cocopeat, Organic matter, Soil degradation.*

INTRODUCTION

Soil is the natural medium for the growth of plants. Soil has also been defined as a natural body consisting of layers (soil horizons) composed of weathered mineral materials, organic material, air, and water. Soil is the end product of the combined influence of climate, topography, organisms (flora, fauna, and human) on parent materials (original rocks and minerals) over time. Soil degradation, as defined by FAO, "is a change in the soil health status resulting in undiminished capacity of the ecosystem to provide goods and services for its beneficiaries. Degraded soils have a health status such that they do not provide the normal goods and services of the particular soil in its ecosystem". Around 24% of the global land area (3500 mha) is covered by degraded soil. Approximately 12 mha of agricultural land is consumed by yearly soil degradation (Bai et al. 2008). Some of the causes of soil degradation

are mentioned in Fig. 1. The type of degradation is determined by various factors such as inherent properties of soil, various climatic factors, terrain characteristics, and vegetation. Food production and environmental protection are seriously threatened by soil degradation, mostly in tropical and sub-tropical regions. Among various measures, one of the mitigation measures to replenish soil organic matter and combat soil degradation is integrated nutrient management and organic amendments involving locally available organic resources and external fertilizers to achieve sustainability. Cocopeat is one such locally available organic material, which is a secondary product obtained from coconut processing industries in abundant amounts.

According to Obeng et al., 2020, about 62-66% of whole coconut comprises shell wastes and husks, which can be used as a helpful resource. Coir waste can't be used as it is obtained first; it has to be washed, given heat treatment, screened, graded, and refined to prepare a cocopeat of different granularity and compactness. There is a stockpile of 10 X 106 metric tons of coir pith in Indian southern states, and it has been estimated that India generates around 7.5 X 105 tons of coir pith every year, which is either burned to dispose of or considered as agricultural waste.

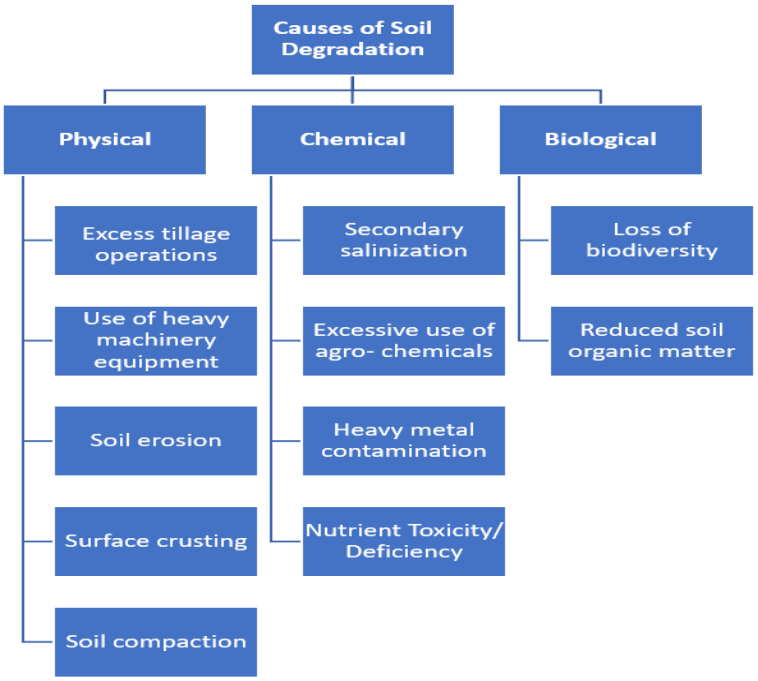

Fig 1: Various causes responsible for degradation of soil fertility. (Source: Srinivasarao et al., 2021)

Properties of cocopeat: Ross (2015) studied the microstructure of cocopeat compounds. They detected the presence of several open cells creating large empty cavities, acting as capillaries for the adsorption of water and nutrients. Due to cocopeat's low cost, availability, and recyclability, as well as its numerous advantages, it is crucial to find its best application for environmental sustainability. Along with high resistance to bacteria and fungi, cocopeat has a high moisture retaining capacity, suitable pH range (Evans et al., 1996), and high cation exchange capacity such that it retains large amounts of exchangeable sodium, potassium, calcium, and magnesium (Mapa and Kumar, 1995). Potassium content in cocopeat is relatively high, but the bulk and particle density of cocopeat is low. It also has the ability to store and release nutrients to plants for more extended periods.

Applications of cocopeat:

- As a soil amendment, Cocopeat could reduce bulk density, increase water holding capacity and improves the organic carbon content of soil (Muthurayar and Dhanarajan, 2013).
- In certain problematic soils, coir pith has shown to remediate pollution affected soils. It was also found to be of great use in recovering salt affected soils (Marimuthu and Nagarajan, 1993; Clarson, 1986) by reducing the salt crust formation and helping in cation exchange process by reducing exchangeable sodium percentage.
- Cocopeat compost is a good nutrients source and performs better when augmented or mixed with nutrients (Ghosh et al., 2007).
- Coir pith contains cellulose, thus can be utilized as reinforcing component in high composite materials.

Growing media: Desirable characters of growing media should be slightly acidic, light in weight so will be easy to transport, good porosity, should allow water to pass through it quickly but with optimal water holding capacity, constant weight either wet or dry, disease-free, silt, clay, and ash content should be low, easy blending and should be easy to store for longer periods of time without any change in physicochemical properties. A high-quality growing medium must give the plant the necessary anchorage, must serve as a reservoir for nutrients and water, should allow oxygen to diffuse to the roots, and permit gas exchange between roots and the atmosphere (Gruda et al., 2013). A strong, fibrous root system is necessary for seedlings to grow quickly, and the growing medium is the main element in determining this. Soil should be incorporated in the potting mixture to provide additional weight for container stability and as a reservoir for moisture and nutrient storage.

Cocopeat as growing media: As coconut fiber is made up of sclerified tissue, it cannot retain much water. However, in a growing medium, these fibers provide necessary aeration through porosity and structure to avoid compaction for the healthy development of the root

zone environment. If combined, Fiber and pith, can prove to be an excellent growing media with a high air-to-water ratio. Raw cocopeat has a high C: N ratio and lignin content, which can immobilize plant nutrients. This repressing effect can be eradicated by using a partially decomposed coir pith. Decomposition of coconut husks reduces the C: N ratio to a level so that it can be successfully used as an organic growing substrate. (George et al., 2013)

Cocopeat is quite similar to sphagnum peat (the most common potting media in horticulture) but has many advantages as a growing media. With increasing demand for commercial horticulture and a reduction in sphagnum peat availability because of the despoiling of ecologically important peat bog areas, cocopeat is acknowledged internationally as an ideal soil amendment and as a component of soilless container media for horticultural applications.

Table 1: Phytochemical constituents in *Clitoria ternatea*

Plant parts	Phytochemicals	Functions	References
Leaf	Alkaloids, reducing sugars, flavonoids, steroids, glycosides	1. Prevention of neurodegenerative diseases and diabetes mellitus 2.Effectively controls the excessive sweating	Scalbert et al., (2005) and Nadkarni, (1992)
Flower	Saponin, Tanin, Alkaloids, Glycosides, Phytosterols, Carbohydrads	1. Anti inflammatory, analgesic 2.Ethanol extract is used as antidiabetic	Srivastava et al., (2009) and Malic et al., (2008)
Root	1,1-diphenyl-2-picrylhydrazyl (DPPH)	1. Antioxidant 2.The root bark is diuretic and laxative; a decoction is given as a demulcent in the irritation of the bladder and urethra	Braca et al., (2002) and Kirtika and Basu, (1980).
Seed	The seeds contain nucleoprotein with its amino-acid sequence similar to insulin, delphinidin-3,3,5-triglucoside, essential amino-acids, pentosan, water soluble mucilage, adenosine, an anthoxanthin glucoside, greenish yellow fixed oil a phenol glycoside, 3,5,7,4-tetrahydroxy-flavone-3-rhamoglycoside, an alkaloid , ethyl D-galactopyranoside, p-hydroxy cinnamic acid polypeptide, a highly basic protein-finotin, a bitter acid resin, tannic acid, 6% ash and a toxic alkaloid.	1. Seeds are cathartic and the root diuretic. 2. Seeds are purgative and aperients 3.Seeds are used in swollen joints, dropsy and enlargement of abdominal viscera	Kirtika and Basu, (1980) and Yoganarasimhan, (2000).

(Source: Lijon et al., 2017)

***Clitoria ternatea*:** *Clitoria ternatea* belongs to the Plantae kingdom, Tracheophyte phylum, Magnoliopsida class, Fabales order, and Fabaceae family. It grows as a perennial climber and is referred to as blue pea flower or butterfly pea and as Aparajita in Bengali. It is found

throughout tropical and subtropical nations and has been well adapted (South and Central America, East and West Indies, China, and India). It can quickly adapt to various soil types (pH 5.5-8.9), including calcareous soils. It can endure both heavy rainfall as well as long drought periods. (Gupta et. al., 2010). It is a highly palatable fodder legume generally preferable over other legumes by livestock. This legume's cultivation and use for animal production will ensure appropriate nutrition and reduce grazing pressure on natural ranges. Because of the appealing flower colours, it comes under ornamental plants that may be utilized as a cover crop, and it also contains bioactive chemicals for therapeutic purposes.

Materials and methods: A completely randomized design was employed with ten combinations of cocopeat and soil. Pots numbered from 1 to 10, and cocopeat was added to each pot in increasing concentrations (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 100%). Pot 1 is considered as a control with no cocopeat at all. Different ratios were prepared using a standard bowl, such as for preparing 02:08 cocopeat: soil ratio, two bowls of cocopeat and eight bowls of soil were added. Among various physicochemical properties of growing media, colour, pH, electrical conductivity, moisture content, water holding capacity, bulk density, porosity, and Total Organic Matter were analysed according to procedures given in the laboratory testing procedure for soil & water sample analysis manual, 2009. Among plant growth parameters, root, shoot, and total plant length, absolute growth rate, fresh and dry weight, moisture content, and Root: Shoot Ratio were studied.

Using a measuring tape, plant height was measured weekly by studying the increase in shoot length. Plant fresh and dry weight, root and shoot dry weight, root/shoot ratio, growth percentage, and plant moisture content were calculated at the end of the experiment.

Result and Discussion

❖ **Effect of cocopeat on moisture content:** Soil moisture content refers to the water content of the soil. Moisture Content increased on increasing ratio of cocopeat in growing media. Maximum moisture content observed in 100% cocopeat media pot (Fig 2). The Cocopeat-modified media mixture's higher moisture content allows for enhanced solubility of nutrients that roots can efficiently uptake.

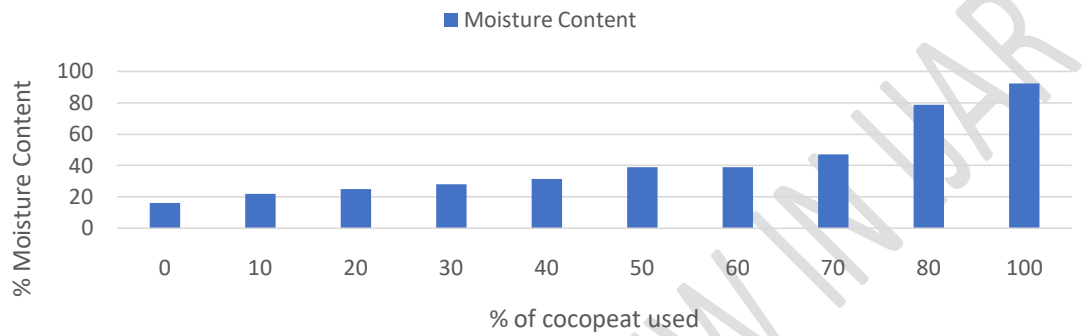

Fig 2: Variation in moisture content of soil media amended with different concentrations of cocopeat

❖ **Effect of cocopeat on water holding capacity:** One of the key markers of soil health and productivity is water holding capacity (WHC), which can be defined as how much water a soil can actually hold against gravity. The WHC of soil samples amended with different concentrations of cocopeat (10% to 100%) increases from 54% to 97% (Fig 3). The soil used for this experiment has less water holding capacity than cocopeat used. When cocopeat was mixed with soil in different ratios it increased water holding capacity of overall media. Soils with higher organic content and finer particle size hold more water than soils with low organic content and coarse particle size. Pesticides and nutrients are less likely to seep from media with high WHC. (Arunrat et. al., 2020 and El-Ramady et. al., 2014).

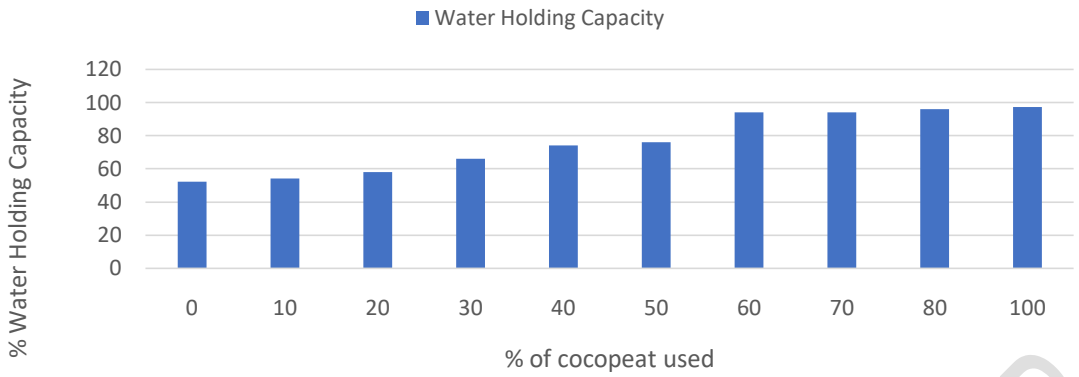

Fig 3: Variation in water holding capacity of soil media amended with different concentrations of cocopeat

- **Effect of cocopeat on bulk density:** Bulk density is an indicator of soil compaction. It is calculated by dividing dry weight of soil by its volume which includes the volume of soil particles as well as volume of pores among soil particles. The bulk density of soil samples amended with different concentrations of cocopeat decreases from 10% to 100%. The bulk density at 10% concentration was 1.543 g/cm^3 and at 100% concentration were 0.215 g/cm^3 as shown in Fig 4. The soil used for this experiment is bulkier than cocopeat used. Bulk density directly affects soil processes and production through its effect on water availability, infiltration, rooting depth, soil porosity, nutrient availability, and soil microbial activity. (Nawaz et. al., 2013). The advantage of lower bulk density value relative to particle density is that it accounts for an increase in pore space which enhances the soil aeration potential and increases water content in soil, hence proves to be a good indicator of media quality (Akaba, 2023).

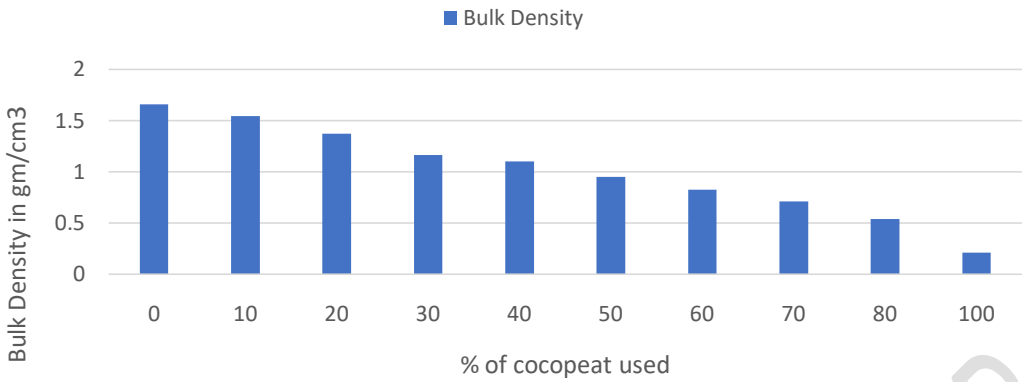

Fig 4: Variation in bulk density of soil media amended with different concentrations of cocopeat

- **Effect of cocopeat on soil porosity:** Percentage of porosity increased from 10% to 100% of cocopeat amended soil media. The % porosity at 10% concentration was 11.8 and at 100% concentration was 37.8 (Fig 5). The media mixture's increased air-filled porosity with increase in the cocopeat percentage, improved water drainage and maintained sufficient air-water balance in pot's limited area. The availability of extra space for the roots to spread out as a result of improved porosity allowed for enhanced nutrient absorption in small volume of potting media (Ilahi et. al., 2017, Awang et. al., 2009).

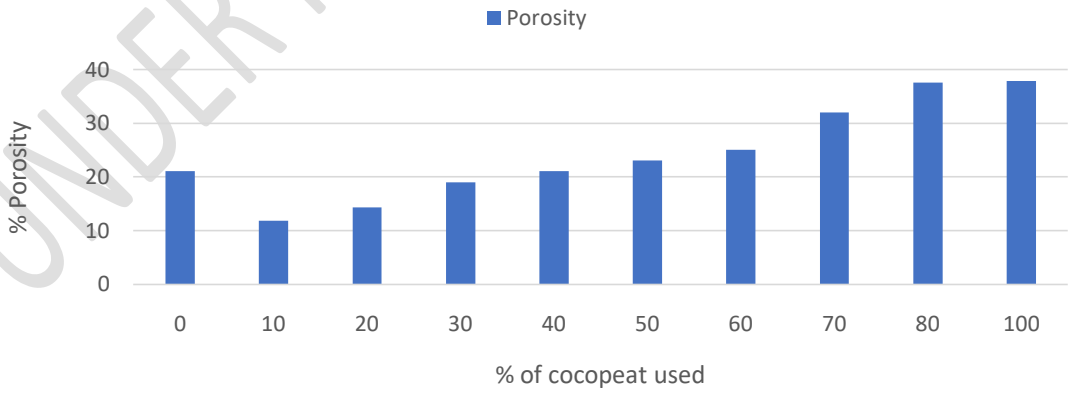

Fig 5: Variation in porosity of soil media amended with different concentrations of cocopeat

Analysis of chemical parameters of soil amended with different concentrations of coco peat

- **Effect of cocopeat on pH:** pH is a measure of hydrogen ion concentration, a measure of acidity or alkalinity of growing media. It is most essential parameter of soil because it is an easily determinable factor and has an effect on other soil properties and soil micro biota community and informs about intrinsic nutrient status of media (Rodolfo et. al., 2018). The pH of soil samples amended with different concentrations of cocopeat decreases from 10% to 100%. The pH at 10% concentration was 8.3 and at 100% concentration was 7.34 as shown in Fig 6. The soil used for this experiment has more pH than cocopeat used.

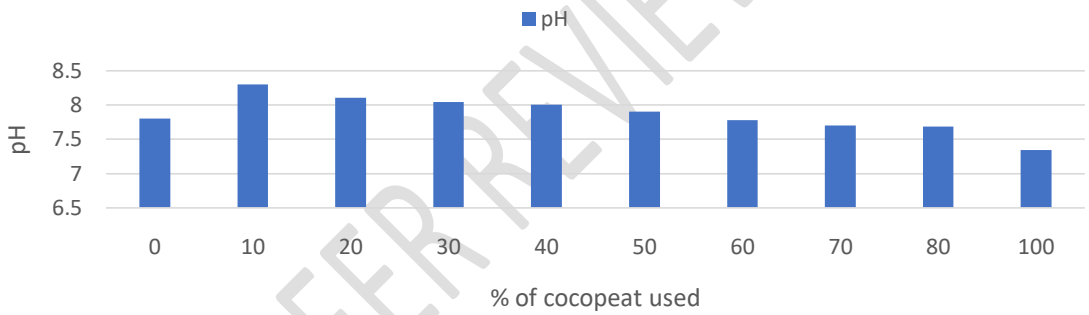

Fig 6: Variation in pH values of soil media amended with different concentrations of cocopeat

- **Effect of cocopeat on EC:** EC values indicate about concentration of inorganic ions in growing media. The EC of soil samples amended with different concentrations of cocopeat increases from 10% to 100% (Fig 7). The EC at 10% concentration was 1.49 mS/cm and at 100% concentration was 2.05 mS/cm. The soil used for this experiment has low EC than cocopeat used. Low EC is indicative of low salinity level in planting media, but also indicates nutrients deficiency to support healthy plant growth. Higher EC indicates higher concentration of soluble salts in planting media which could enhance plant growth (Ding et. al., 2018., Machado and Serralheiro, 2017)

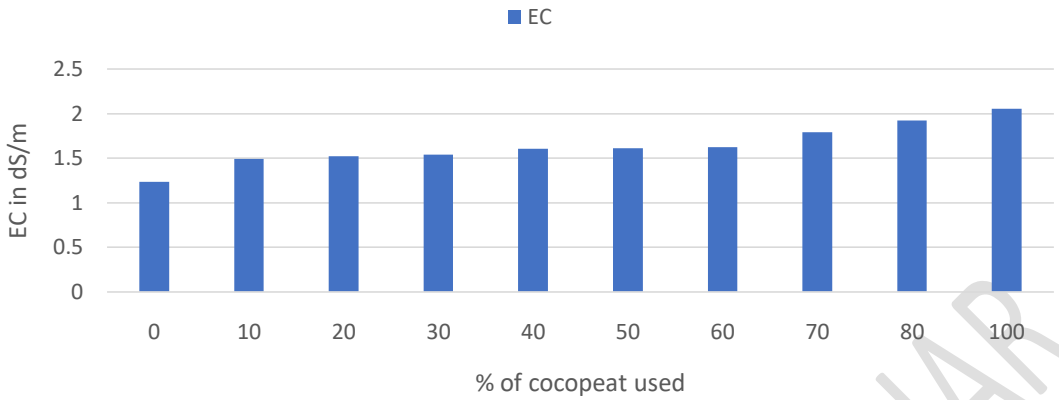

Fig 7: Variation in EC values of soil media amended with different concentrations of cocopeat

- **Effect of cocopeat on Total organic matter:** The total organic matter is a measure of amount of organic carbon present in the sample. Maximum percentage of organic matter is observed in 100% cocopeat i.e., 0.42% and minimum in 10% concentration of cocopeat i.e., 0.2% as shown in Fig 8. The soil used for this experiment has low total organic matter than cocopeat used as cocopeat is itself an organic planting media. Soil with higher organic matter holds more water than soil with low organic matter which is beneficial for plant growth. On long term basis, use of cocopeat for soil amendment could improve the soil organic carbon content (Muthurayar and Dhanarajan, 2013).

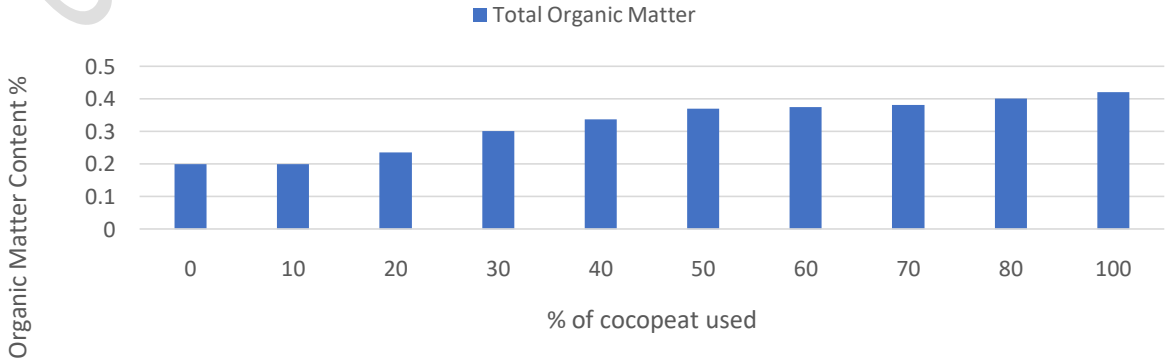

Fig 8: Showing organic matter content of soil media amended with different concentrations of cocopeat

Analysis of effect of cocopeat on morphological parameters of aparajita plant

- **Effect of cocopeat on shoot and root length of plant:** It is clearly visible from findings of current work that cocopeat application showed positive effect on shoot length as compared to control (100% soil). As a source of all essential macro and micronutrients in their usable forms during mineralization and enhancing the physical and chemical parameters of soils, cocopeat has a direct role in plant growth. Maximum shoot length observed on soil amended with 50% cocopeat indicating maximum plant growth in terms of height (Fig 9). Plant growth inhibited on 100% cocopeat media may be due to poor aeration caused by high water holding capacity of cocopeat. Cocopeat application showed positive effect on root length too as compared to control (100% soil).

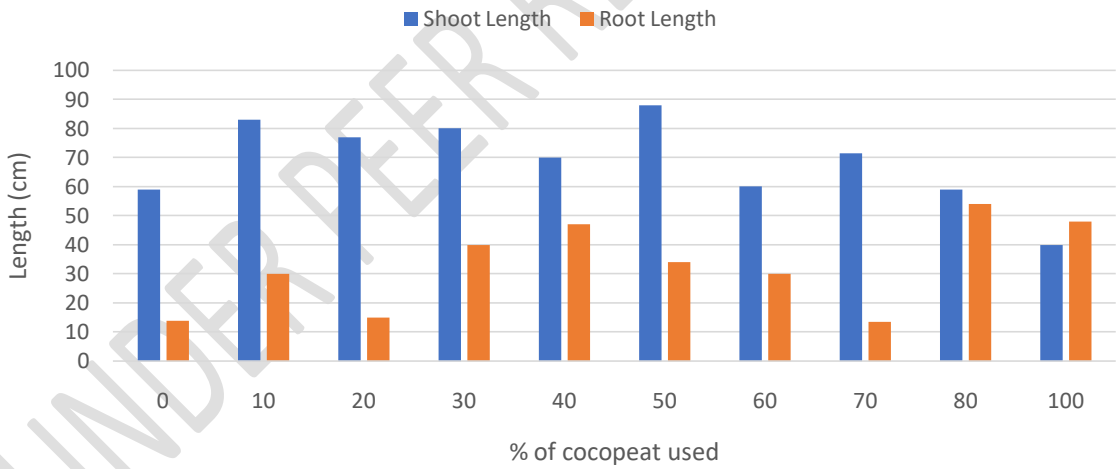

Fig 9: Average shoot and root length of aparajita plant in different concentrations of cocopeat

- **Absolute Growth Rate (AGR):** It can be simply defined as rate of increase in size of plant per unit time. It is an index to measure growth rate of plant. It can be used to compare growth of plants of same age or same initial size or height. From Fig 10, it can be concluded that maximum rate of increase in plant height is observed in soil amended

with 50% cocopeat while minimum in 100% cocopeat indicating growth inhibition in 100% cocopeat. Similar results were also obtained by Kukal, 2014.

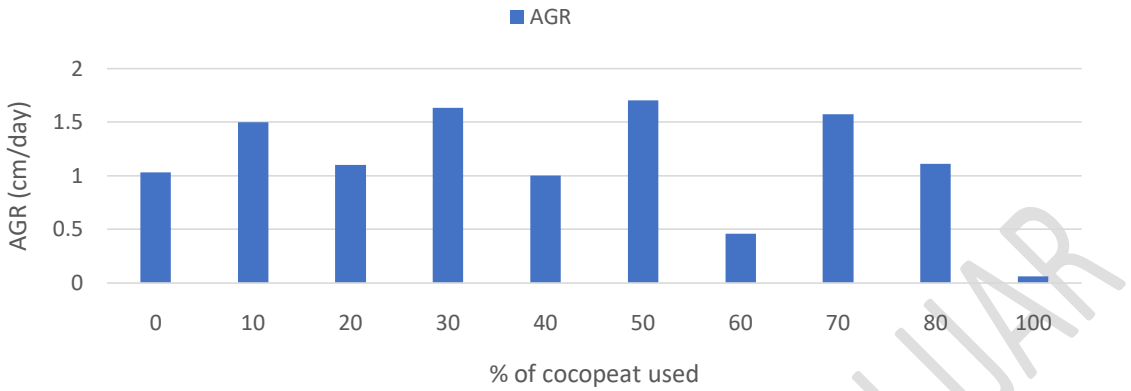

Fig 10: Absolute growth rate of aparajita plant in different concentrations of cocopeat

❖ **Effect of cocopeat on fresh and dry weight of plant:** Biomass of seedlings mainly depends on height, diameter and root growth. As water content in plant tissues can fluctuate greatly depending on environmental conditions, dry weight is more consistent and reliable method to measure plant growth (Bebre et. al., 2022, Louise et. al., 2013). According to result obtained, maximum of the cocopeat treatments showed positive effect on dry weight of plants when compared to control (100% soil). Maximum dry weight is observed in plant grown in soil amended with 50% cocopeat showing maximum plant growth in terms of dry weight (Fig 11 and Fig 12). Similar results were studied by Cahyo et. al., 2019, Khan et. al., 2019. Moisture content varied greatly in plants against control. Maximum water content is found in plant grown in only soil.

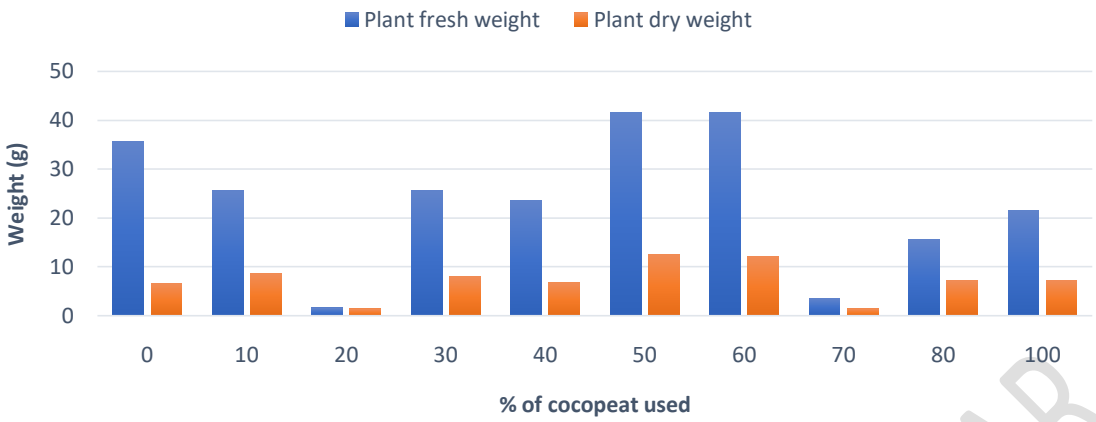

Fig 11: Fresh and dry weight of aparajita plant in different concentrations of cocopeat

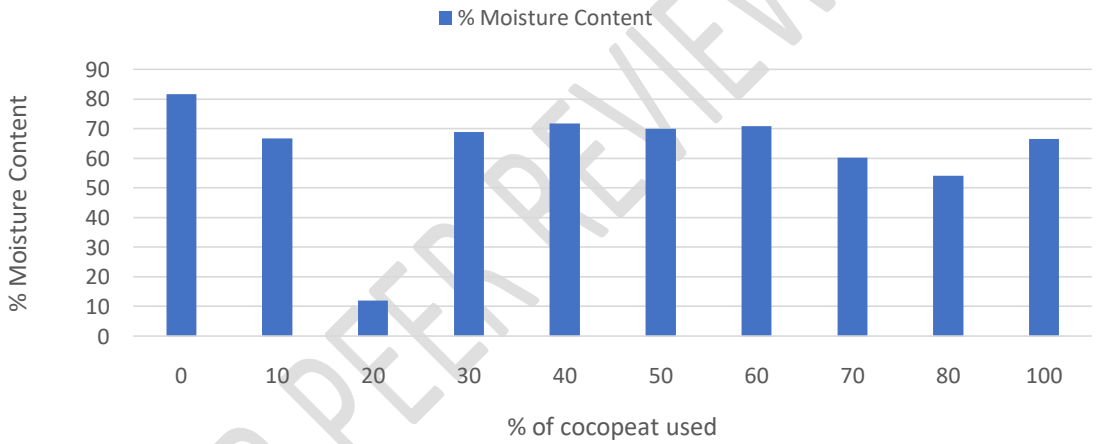

Fig 12: Moisture content of Aparajita plant in different concentrations of cocopeat

❖ **Root: Shoot Ratio:** From the observations, it can be concluded that highest root/shoot ratio is observed in plant grown in 50% cocopeat media as shown in Fig 13. Higher root/shoot ratio ensures better survival rate and growth rate after planting seedlings. Those seedlings with superior root systems have better chances of growth, survival and are drought resistant thus, can endure any environmental condition easily (Louise et. al., 2013)

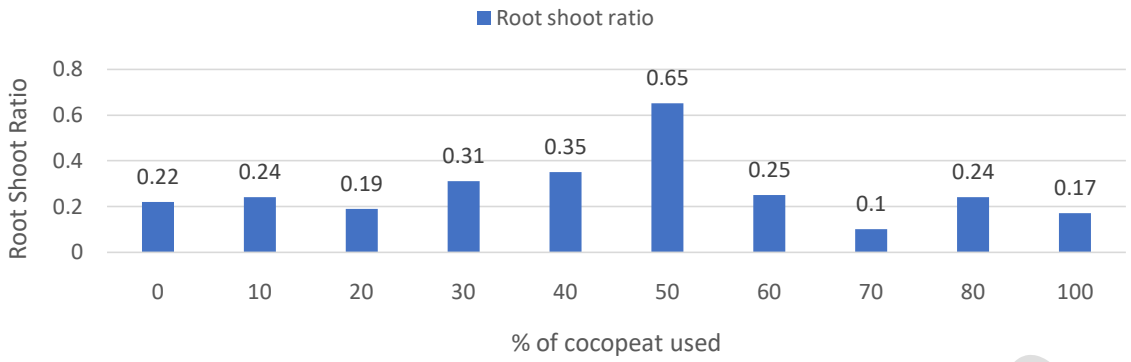

Fig 13: Root: shoot ratio of aparajita plant in different concentrations of cocopeat

❖ **Shoot: Root Ratio:** Due to direct relation between shoot and root sizes and water loss and uptake, the shoot root ratio is a useful predictor of internal water stress and possible survival of an out planted seedling. (Yang et. al., 2021, Blaha 2019) Lowest shoot/root ratio is detected in plant grown in soil amended with 50% cocopeat showing better plant growth as shown in Fig 14. Seedlings with lower shoot-root ratios able to survive better because of immediate reduction of moisture stress and desiccation after planting and low internal water stress allows better root growth which improves the root system's ability to absorb water (Zia et. al., 2021, y et. al., 2020). In comparison to the surface area of the roots, seedlings with high shoot-root ratio will have a larger transpiring surface, which can be harmful for seedling during drought conditions.

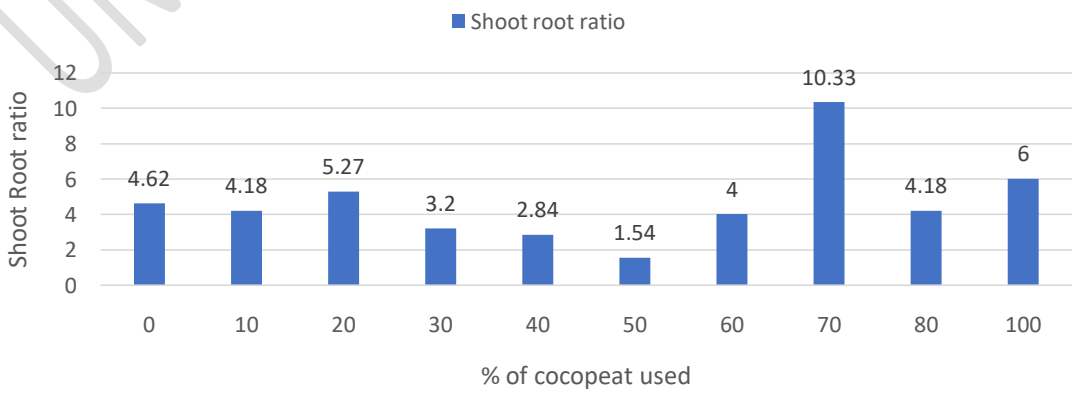

Fig 14: Shoot: root ratio of aparajita plant in different concentrations of cocopeat

Conclusion

From the present study, it can be concluded that cocopeat application improved soil's inherent physical and chemical properties. From current investigations, the soil used had a water holding capacity of 52%, but on applying cocopeat in increased concentrations, WHC gradually increased and reached 96%; similarly, porosity went from 21% to 37.5%. Low bulk density helps in easy transportation and application of cocopeat to soil, decreased bulk density to 0.538 gm/cm3.Regarding chemical parameters, cocopeat application showed an insignificant effect on soil pH but, on the other hand, increased electrical conductivity of soil. Incorporation of cocopeat to soil also boosted its organic matter content, which is a measure of total organic carbon, and total organic matter plays a significant role in the healthy growth and development of seedlings. Plant growth can be defined as a non-reversible, quantitative increment in height, mass, or volume of a plant or its parts. In this study, plant growth is studied by observing an increase in height and dry weight of seedlings with time. Compared to the control (100% soil), cocopeat application positively affected morphological parameters of aparajita seedlings indicated by enhanced seedling height, root length, and dry weight of plants. When comparing various compositions of soil and cocopeat, the best composition for the growth of *Clitoria ternatea* seedlings) is 50:50, i.e., equal amounts of both soil and cocopeat. Plants grown in 50% cocopeat media showed maximum plant growth indicated by maximum seedling height, i.e., 88 cm, and highest dry weight, i.e., 12.5g.

To use cocopeat as growing media, it needs organic amendments, as in this case, soil incorporation along with fertigation. Thus, it can be concluded that 100% cocopeat is not suitable for the growth of *Clitoria ternatea* seedlings as AGR (an indicator of plant growth) observed in the case of 100% cocopeat is just 0.06, which is the least among all the treatments.

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