__Original Research Article__

Effective media validation, benefits and costs for achieving high yield in ribbed gourd in soilless culture under matric suction irrigation

ABSTRACT

Aims: To standardize an appropriate method of finding suitable particulate organic substrates for composing soilless media, a soilless experiment was conducted in an open wasteland area in pandal system under matric suction irrigation

Study design: Completely Randomized Design

Place and Duration of Study: Department of Soil Science and Agricultural Chemistry, AnbilDharmalingam Agricultural College and Research Institute, Trichy, Tamil Nadu during *Rabi* 2020-2021

Methodology: Three growing media were tested with ten replications. For composing the growing media equal proportion (on aweight basis) of substrates *viz*., coirpith, vermicompost, flyash, green manure (Dhaincha), and sand were mixed in different combinations. Ribbed gourd CoH-1 was raised in growing media in containers that were interconnected by tubs and tubes to maintain moisture always by matric suction irrigation technique.

Results: Growing media having Coirpith: Vermicompost: Green Manure: Sand registered the highest fruit yield (10.033 kg pot^{-1}), water use efficiency (411.2 kg fresh fruit mm^{-1}) and benefit-cost ratio (1.95) than that of the growing media combination with flyash. This green manure combination significantly recorded 18% more yield and water use efficiency than that of thecoirpith and vermicompost combination. Apparent nutrient recovery was highest in the growing media with coir pith: vermicompost: green manure: sand for N (22.42%), P (23.47 %), and K (192.9 %).

Conclusion: Exploitation of the potentiality of particulate organic materials demonstrated in thissoilless system technique may be useful for farmers to generate additional farm income with proper use of particulate organic substrates obtainable/ available in their farm.

Keywords: flyash, green manure, growing media, matric suction, ribbed gourd, substrates, sand,

1. INTRODUCTION

"The diverse climate and physio-geographical conditions of India ensures growing various kinds of horticultural crops. Owing to that India stands as the second largest producer of vegetable crops accounting for 15 per-cent of the World production" [1]. "The vegetable production in India has increased by 25.6% over the last nine years from 169.48 million metric tons in 2014-15 to 212.91 million metrictons in 2022-23"[2]."Vegetables are a major source of vitamins like niacin, riboflavin, thiamin, vitamin A, and vitamin C. In addition, they supply minerals like calcium and iron, proteins, and carbohydrates and are important sources of dietary fiber and antioxidants"[3,4, and 5].

"*Luffa*, the popular fibrous fruit vegetable in the family of Cucurbitaceae, is said to have originated in India and isalso grown throughout the country and in many parts of the world. It is a creeper and has a climbing or trailing habit. It is also called ridge gourd or ribbed gourd in many regions. The green immature fruits are cooked as vegetable. Ribbed gourd fruits chemically constitute carbohydrates, carotene, fat, protein, phytin, flavonoids, saponin, amino acids, luffangulin, sapogenin, oleanolic acid and cucurbitacin B. It contains a good amount of fiber, vitamins and minerals including Vitamin B_2, Vitamin B_3 and Vitamin C, carotene, calcium, phosphorus, and iron in small quantities" [6]. "Fresh fruits can supply about 300 µg β-carotene and 1000 µg carotenoids per 100 g. Hence it has various pharmacological actions like hepatoprotective, antidiabetic, antioxidant, abortifacient and antifungal activity. It is recommended for purifying blood, as an appetizer, as alaxative, cure for jaundice, reducing weight, as an anti-inflammatory and antibiotic, strengthening ofthe immune system, skin cure and for the health of thestomach" [7].

Feeding millions in India is getting increasingly difficult as the population grows, urbanization spreads, and industrialization accelerates. Although the population is growing at a quicker rate, agricultural land capacity can only rise by 2%. An estimated 342 million tons of vegetables will be required to meet consumer demand by 2050. As a result, growing vegetables using containers appears to be a promising strategy for increasing crop productivity and intensity [1]. Soilless culture, the most sustainable and environmentally acceptable alternative to traditional soil-based intensive agriculture, is now regarded as a convenient approach for conserving energy, fertilizers, and water. Specifically, by changing fertigation solution volume and nutrient concentration according to crop demand, proper augmentation in yield and fertilizer usage efficiency can be obtained without accumulating pollutants [8].

Organic substrates such as manures and composts have long been used to compose growing media, giving beneficial characteristics such as water retention, aeration, and nutrient availability. Bulky materials that are readily available locally are typically selected to formulate low-cost growing media. Coirpith and vermicompost are particularly popular. Green manures rich in nitrogen and phosphorus breakdown quickly, therefore they can also be utilized as a substrate in the form of dry powder. Furthermore, flyash, an oxidized inorganic substance that accumulates in pyrogenic industrial premises, has some desirable substrate qualities. Individually, no substrate qualifies for usage as soilless media, and each may have limitations. These common limitations of these substrates include undesired salinity, bulk density, aeration, water holding capacity, pH, and so on. These constraints can be mitigated by choosing the right combination of substrates.

"Matric suction irrigation is a technique for continually supplying moisture to the growing media from bottom to top during the crop period. Containers (plastic pots) holding growing material are placed in tubs with standing water. All baths are connected via tubes. Each tub has the same level of standing water. Water lost through evapotranspiration in tubs is promptly replenished from the storage tank. There is no nitrogen loss due to leaching or drainage of water. Previously, a study with growing media and fertilization methods revealed that coirpith, vermicompost, and fly ash were the most suitable substrates for growing snake gourd in soilless culture" [9]. Further, Elakiya and Arulmozhiselvan [10] evaluated the effect of salinity and media composition on thegrowth and yield of ribbed gourd in soilless culture under matric suction irrigation. In the present study, acontainer experiment with ribbed gourd was conducted in order to validate the effective growing media for obtaining high yield of ribbed gourd in pandal system under matric suction irrigation to choose the best-growing media combination.

2. MATERIAL AND METHODS

The location of theexperiment is AnbilDharmalingam Agricultural College and Research Institute, Trichy, Tamil Nadu ($10^0$45.205'N, $78^0$36.141' E, Altitude: 85 m MSL), which is part of Tamil Nadu's Cauvery delta agro-climatic zone, which has a tropical environment with an annual average rainfall of 860 mm. The soilless container study (pot experiment) was carried out in an open wasteland area using a test crop of ribbed gourd *(Luffa acutangula* L.) in a pandal structure (climber support) coupled with a matric suction irrigation system (Fig. 1). The pandal structure was built to support vines at a height of around 6 feet by installing 30 concrete pillars and linking them on top with steel wires.

2.1 Assembly of matric suction irrigation system

"The setup of soilless container culture with matric suction irrigation was established using the design and materials originally described for theopen land soilless system"[9,10]. In the method of irrigation by matric suction moisture is continuously supplied to growing media without breaking from bottom to top. Matric suction of growing media is the force with which water is adsorbed on the physical surfaces of substrate particles. In this validation study, the substrates used were coir pith, vermicompost and green manure (Daincha). The mineral/ inorganic constituents viz., fly ash and sand (<1.0 mm) were used in combination. Standing water is present all the time in tubs which wets the bottom of containers and in turn the growing media is wetted.

The components (Fig.2) of this system were (1) an overhead water tank, (2) A steady water level tub with ball valve assembly, (3) A series of plastic tubs interconnected through 20 mm black HDPE tubes and (4) Plastic 20 L capacity container filled with growing media. The series of tubs set on level platforms were linked through the steady water level tub to the storage tank, and by doing so, all tubs were aligned to the same level, ensuring that water was filled uniformly at all times by gravitational flow.

The plastic 20 L container comprises 8 holes (10 mm in diameter) at the bottom. A nylon mesh (No. 400) measuring 18 x 18 inches square was inserted into the bottom of each container and filled to a height of 4 inches with manufactured sand (m-sand) as the base media. The base media was partially submerged in the water contained in the tub. Above the base media, a nylon mesh (No. 400) with a square dimension of 18 x 18 inches was put to prevent the downward migration of growing media particles. Growing media was spread over the mesh until it reached a height of nine inches. The base media is hydrated through matric and capillary suction, initially by contact with water, and then maintained at analmost saturated moisture content. The growth material was successively hydrated using solely matric suction. The base media is always at a lower matric suction. When the particle surfaces of growth media are empty of water due to evaporation or transpiration, the matric suction increases. This scenario provides a matric suction gradient, which works as a driving force, causing water to migrate upward from the base media to the growing media via particle-to-particle contact.

Fig.1. View of soilless media experiment in pandal structure

Concrete slabs (2 x 2 feet) were installed over a brick work adjacent to the 30 concrete poles fixed for the pandal construction (6 lines x 5 rows) with a 10-foot spacing on either side. The concrete slabs were firmly aligned at a constant height using the tube level. The tubs were put on concrete slabs. Each tub had a growing media container. Each container was filled with growth media based on the randomization of treatments (Fig.3).

a) Overhead water tank b) Steady water level tub c) Container inside plastic tub

Fig.2. Components of matric suction irrigation assembly

"The treatments imposed consisted of 3 combinations of media and accordingly, the containers were arranged in acompletely randomized design, with 10 replications (Table 1). The treatments were designed to validate the well performed growing media in previous experiments to evaluate the effect of salinity and composition of media on thegrowth and yield of ribbed gourd in soilless culture under matric suction irrigation" [10]. The test crop of ribbed gourd (hybrid CoH1) was raised in the season *Rabi* 2020–2021.

Table 1 Treatment details of the pandal experiment

Particulars	Details	Composition of Media
Experimental design	Completely Randomized Design	T_1 CP+VC+S (1:1:1)
No. of treatments	3	T_2 CP+VC+FA+S (1:1:1:1)
Replication	10	T_3 CP+VC+GM+S (1:1:1:1)
Test crop	Ribbed gourd (CoH 1)	CP - Coirpith
Duration	120 days	VC - Vermicompost
Season	*Rabi* (October – March)	GM - Green manure
Spacing	10 feet x 10 feet	FA - Fly ash S - Sand
Experimental plot size	5 cents	() - Ratio of mixing on weight basis

In the water storage overhead tank, non-saline water (EC 0.34 dS m^{-1}) was stored for continuous watering. Water from the tank was cycled to all of the tubs and containers. Once a week, the height of standing water inside the tank was measured with a graduated scale. Based on the previous measurement's decrease in water height, the volume of water consumed for cropping was determined for a given period (area of tank x drop in height). The salinity of the media was monitored every time of fertilizer application, one day before and one day after. The salinity of the growing media was determined by measuring electrical conductivity in the filtrate obtained after cloth filtering the suspension made by soaking two grams of growing media in 100 mL of distilled water for 30 minutes. The measured electrical conductivity was multiplied by ten to get the values in dS m^{-1} for a substrate-water ratio of 1:5. The pH of the same filtrate was measured with a pH meter, and the findings were expressed by subtracting one unit of pH from the observed value to compensate for dilution.

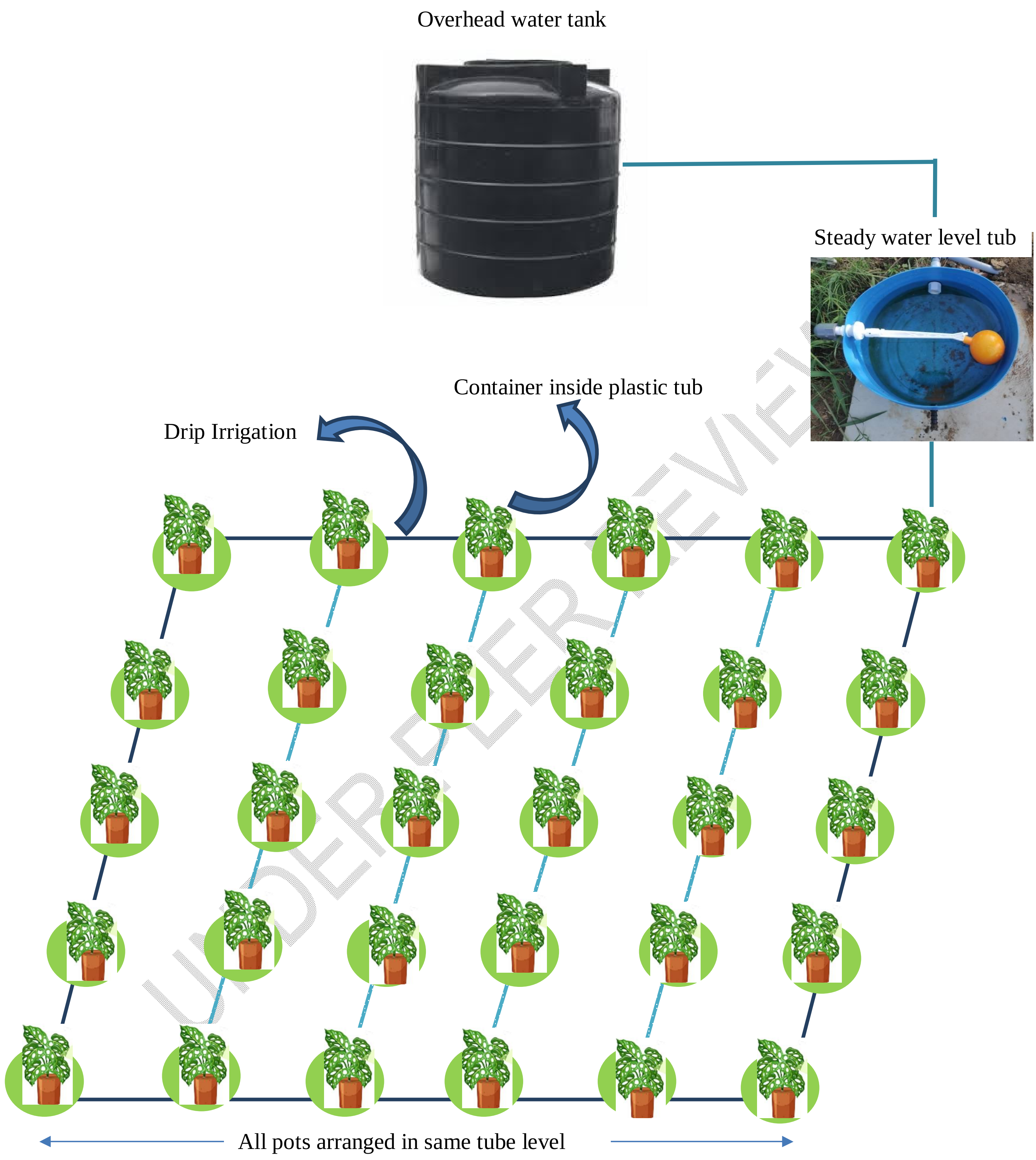


Fig.3. Illustration of ribbed gourd plant placed in plastic tubs, drip line, steady level water tub and overhead tank during pandal experiment

2.2 Fertilization of crop

For this soilless experiment with ribbed gourd crop, the dose of primary nutrients adopted was 125g N, 25 g P_2O_5 and 25 g K_2O per container. The calculated quantity of water-soluble fertilizers *viz*., urea, mono ammonium phosphate (MAP) and muriate of potash (MOP) were taken and applied to each container in 19 split doses at 5 days intervals. Specific fertilizer dose at specific crop stage was done by adding to the irrigation water stored in the tank for circulation to all containers. For supplying secondary and micronutrients commonly, a nutrient solution was prepared by taking 30 g of fertilizer mixture comprising 5 g $MgSO_4$, 5 g $CaCl_2$, 3 g $FeSO_4$, 3 g $ZnSO_4$, 2 g $CuSO_4$, 2 g $MnSO_4$ and 10 g Citric acid and dissolving in 1 L of water. At weekly intervals 100 ml of this nutrient solution was added to water in the storage overhead tank.

2.3 Culturaloperations, climber support and observations

All plant protection measures were carried out periodically to control pest and diseases during ribbed gourd crop growth as per recommendations. A uniform dose of 30 g of *Pseudomonas fluorescens*, 30 g of *Trichodermaviride*, 10 g ofFuradon and 10 g ofFenvalerate was added to all the growing media mixture. As a natural means of insect control neem cake (0.5 kg container^{-1}) was applied over the surface of the media mixtures particularly to prevent the coconut grub attack.

Spraying of neem-based products was done initially in the vegetative stages to control the sucking pests. Fruit fly traps with Chipku pheromone lure were installed in the experimental area to monitor the fruit fly (*Bactroceracucurbitae*) population in the area prior to flower initiation, which helped in reducing the number of flies in the experimental area. Neem oil @ 3% was foliar sprayed, whenever the observations of number of fruit fly in the traps were higher. For restricting algal growth on the surface of the water tubs, metal sheets were cut in a square shape and placed over the surface of the blue tubs as a lid. A round shaped hole was made at centre to keep the container on the water tubs. In addition, the containers were covered around with chick mesh net to prevent damage of the seedlings and young plants by peacocks and squirrels.

2.4 Statistical analysis

The statistical analysis of growing media and method of fertilization on plant growth and yield parameters of crops, nutrient content, nutrient uptake and nutrient use efficiency were subjected to analysis of variance as described by Panse and Sukhatme [11].

3 RESULTS AND DISCUSSION

Growing vegetable crops provides farmers more since they grow faster, have a longer yielding period, and are more easily marketable. When viable land for vegetable production becomes scarce, techniques such as soilless culture may offer an alternate solution. The current study was conducted to standardize the soilless culture method for the production of pandal vegetable crop in plain wasteland areas using typically organic/mineral substrates available near farmers' holdings. The effect of composition of themedia was studied by relating initial properties of substrates to the growth, yield, nutrient uptake and water use performances of the crop. At harvest stage vegetative parameters viz., leaf width, vine length and vine drymatter and yield parameters viz., fruit length, number of fruits harvested and fruit drymatter were recorded. The yield of fruits was recorded on afresh weight basis for every container (pot). Harvest Index was calculated as the ratio of fruit drymatter to total (vine +

fruit) drymatter. Water productivity was calculated by dividing fresh weight of harvested fruits (in kg ha^{-1}) by the total amount of water consumed (in mm).

3.1 Initial characteristics of growing media

The different growing media studied were prepared from substrates which had wide variability in their physico-chemical properties (Table 2). Among the substrates, the content of soluble salts was high in daincha (EC 13.43 dS m^{-1}) followed by coirpith (EC 8.43 dS m^{-1}), whereas moderate soluble salt content was found in vermicompost (EC 1.86 dS m^{-1}) and flyash (EC 1.14 dS m^{-1}). The reaction state of coirpith and daincha were near slight acidic where as vermicompost and flyash were slight alkaline. The total dissolved solids (TDS) estimated was highest in daincha (6612 mg L^{-1}) and moderate in coirpith (4292 mg L^{-1}) .Very high content total nitrogen (N) was present in daincha (22.412 g kg^{-1}). High total phosphorus (P) was estimated in vermicompost (5.065 g kg^{-1}). Total potassium (K) was abundant in daincha (4.082 g kg^{-1}), followed by coirpith and flyash.

Table 2 Physico-chemical properties and nutrient content of substrates

Physical properties and chemical composition						
S. No.	**Parameter**	**Unit**	**Coirpith**	**Vermicompost**	**Flyash**	**Daincha**
1.	Bulk density	Mg m^{-3}	0.118	0.592	1.059	0.255
2.	Water holding capacity	%	426.31	52.85	46.48	56.85
3.	Total Carbon	%	33.84	16.62	0.78	35.64
4.	TDS (1:5 dilution)	mg L^{-1}	4296	886	516	6612
5.	pH (1:5 dilution)	pH	6.49	7.46	7.88	6.59
6.	EC (1:5 dilution)	dS m^{-1}	8.53	1.86	1.14	13.43
7.	C/N Ratio	-	52.9	25.1	16.2	17.7
Nutrient Composition						
8.	Total N	g kg^{-1}	2.821	11.265	1.134	22.412
9.	Total P	g kg^{-1}	0.193	5.065	0.699	3.810
10.	Total K	g kg^{-1}	2.324	1.162	0.456	4.082

3.2 Vegetative and yield parameters of ribbed gourd

The effect of treatments on thegrowth of ribbed gourd vine was estimated by recording leaf width, vine length and vine drymatter at harvest stage (Table 3).The highest leaf width (27.17 cm), vine length (5.55 m) and vine drymatter (1500.6 g pot^{-1}) were recorded with plant raised in the growing media (Fig.4) containing of Coirpith: Vermicompost: Green manure: Sand (T_3). Growing media consisting of Coirpith: Vermicompost: Fly ash: Sand (T_2) showed relatively high growth in leaf width (25.15 cm), vine length (5.52 m) and vine dry matter (1403.2 g pot^{-1}). The lowest leaf width (22.48 cm), vine length (4.90 m) and vine drymatter (1306.7 g pot^{-1}) was registered in growing media comprising Coirpith: Vermicompost: Sand (T_1) (Fig.5).

Significant variation was recorded in the yield and yield parameters of ribbed gourd fruit yield due to the influence of growing media selected for validation (Table 3). The fruits of plants raised in coirpith: vermicompost: green manure: sand (T_3) recorded the highest fruit length (37.61 cm), number of fruits per pot (30.4). Fruit yield per pot followed the order: coirpith: vermicompost: green manure: sand (T_3) (10.033 kg pot^{-1}) > coirpith: vermicompost: fly ash: sand (T_2) (9.470 kg pot^{-1}) > coirpith: vermicompost: sand (T_1) (8.220 kg pot^{-1}). The highest dry matter was recorded by the growing media comprising coirpith: vermicompost: green manure: sand (T_3) (666.8 g pot^{-1}) which was comparable with coirpith: vermicompost: fly ash: sand (T_2) (662.8 g pot^{-1}).

Table 3 Effect of treatments on vegetative and yield parameters of ribbed gourd

T.No	Vegetative parameters			Yield parameters			
	Leaf width	Vine length	Vine drymatter	Fruit length	No. of fruits harvested	Fruit Yield (fresh weight)	Fruit drymatter
	cm	m	g pot^{-1}	cm	Nos. pot^{-1}	kg pot^{-1}	g pot^{-1}
CP+VC+S	22.48	4.90	1306.7	33.51	24.2	8.220	529.9
CP+VC+FA+S	25.15	5.52	1403.2	35.40	26.8	9.470	662.8
CP+VC+GM+S	27.17	5.55	1500.6	37.61	30.4	10.033	666.8
SEd	0.361	0.084	18.82	0.413	0.38	0.131	8.06
CD (P=0.05)	0.615**	0.142**	32.05**	0.703**	0.64**	0.224**	13.73**

Growth measured by vine length and number of leaves, and yield parameters viz., fruit length, fruit girth, single fruit weight, total fruits harvested and fruit drymatter of ribbed gourd was highest in growing media containing coirpith: vermicompost; green manure: sand, which consequently resulted in the highest fruit yield. Relatively high yield was obtained when green manure was substituted with flyash. Yield of fruits was moderately high when growing media contained coirpith and vermicompost with sand. Coirpith, vermicompost, flyash and green manure as the stable physical substrate, vermicompost, green manure, and flyash as the nutrient supplier, and sand as a material to improve porosity have been well established in the present study confirmatively.

Chanda*et al*. [12]“discovered that combining vermicompost with inorganic fertilizers enhanced the fruit weight and yield of bitter gourd”. Anuja and Poovizhi [13] reported similar findings in cucumber, as did Kameswari*et al*. [14] in sponge gourd. When vermicompost was put to sand + rice husk substrate, it increased vegetative growth and production of celery and red cabbage by up to 20% [15]. “Similarly, adding vermicompost as a substrate has been shown to improve both the growth and the yield of sweet paper, snap beans, lettuce, strawberries, celery, salad cabbage, and red cabbage”[16,17].Arancon*et al*.[18] in ribbed gourd and Soobhany*et al*. [19] in green beans both proposed that the presence of substances such as humic acid in vermicompost could have had a direct encouraging influence on growth and yield in addition to nutritional provision. Because vermicompost contains a high concentration of organic matter, it would have improved the physical and chemical qualities of growing media while also providing nutrients, as demonstrated by experiments conducted by Arancon*et al*. [20] on tomato and peas and Arancon*et al*. [21] on strawberry.

The growth and yield of ribbed gourd were significantly higher in the growing substrate that contained flyash. Flyash increased crop production and biomass [22,23], therefore it is used as fertiliser to improve the productivity of many crops [24,25] because it includes essential elements such as K, Mg, and S [26]. The favourable impact of flyash on plant growth and biomass production has been explored in wheat [27], rice [28], carrot [25], radish [29] and safedmusli[30]. About 15 per-cent increase in terms of shoot length, shoot fresh and dry weight, number of leaves, and leaf area in beetroot was reported with fly ash application [31].

Munda *et al*. [32]"found that using biochar and flyash increased the number of tillers per plant in rice, which could be attributed to the rise in very high porosity and water holding capacity". "The absolute hollow silt-sized particles in flyash may facilitate transport and supply water molecules" [33]. "In studies with bottle gourd and sponge gourd, application of flyash at 120 and 180 Mg ha^{-1}, respectively, increased yield by 10-15%" [34]. According to Yeledhalli*et al*. [35], applying fly ash increases soil bacteria count and enzyme activity of dehydrogenase, urease, and alkaline phosphatase.

Daincha, the most popular green manure crop, thrives well in both saline and alkaline soils. Bhuiyan*et al*. [36] found that roughly eight weeks old dhaincha plants had 3% N in addition to other nutrients. The addition of Daincha as dry powder to vermicompost and coirpith resulted in a considerable boost in growth and yield parameters.

Fig.4. Experimental view of ribbed gourd at yielding stage

3.4 Nutrient uptake

The treatments imposed set prominent variations on nutrient uptake of the vine and the fruit of ribbed gourd (Table 4). The highest amount of total N (28.795 g pot^{-1}), total P (2.821 g pot^{-1}) and total K (44.052 g pot^{-1}), total Ca (18.896 g pot^{-1}), total Mg (11.395 g pot^{-1}) and total S (6.627 g pot^{-1}) uptake was observed in the growing media comprising of Coirpith: Vermicompost: Green Manure: Sand (T_3).

Table 4 Effect of treatments on nutrient uptake, harvest index and water productivity

T.No	Total nutrient uptake (g pot^{-1})					
	N	P	K	Ca	Mg	S
CP+VC+S	23.144	2.128	33.500	15.368	8.303	5.260
CP+VC+FA+S	26.741	2.591	42.935	17.780	10.413	6.540
CP+VC+GM+S	28.795	2.821	44.052	18.896	11.395	6.627
SEd	0.846	0.061	1.116	0.686	0.361	0.216
CD(P=0.05)	1.441**	0.104**	1.901**	1.168**	0.615**	0.368**

Application of fertilizer nutrients through irrigation water in split doses was effective in getting distributed to all growing media causing adequate uptake by plants. Possibly use of low-saline irrigation water and continuous availability of nutrients in growing media might have resulted in high uptake of nutrients by ribbed gourd in the drymatter of vine and fruits. Particularly growing media containing coirpith: vermicompost: green manure: sand recorded the highest nutrient uptake of N, P, K, Ca, Mg and S. In this particular combination, especially the effect of green manure would have been much more pronounced contributing more nutrients. Chanda *et al*. [12] found that incorporation of dhaincha remarkably increased soil pH, SOC, N, P, K and S contents in soil when compared to initial soil status. Increased nutrient supply reached a peak upto 50 days after incorporation and declined thereafter except K and S. Similarly, the goat manure in combination with *Azolla* and *Sesbania* improved organic carbon, nitrogen, and C/N ratio of the soil over the initial value [37].

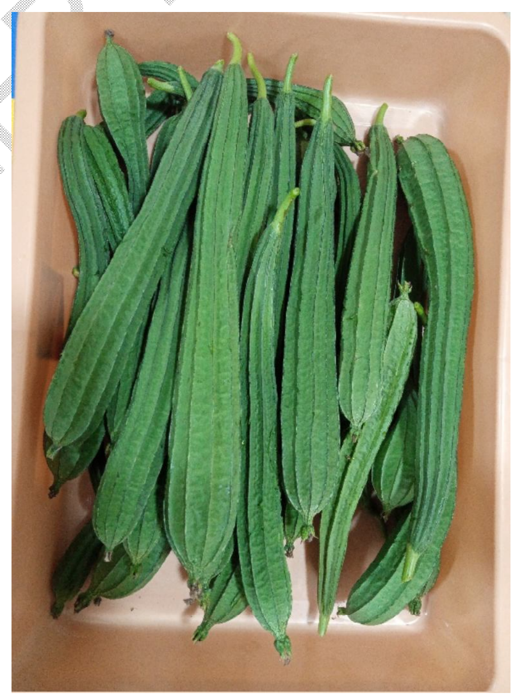
“The availability of adequate nitrogen in the vegetative phase could lead to numerous physiological and metabolic processes, as it is intimately associated with protein formation, tissue growth, physiological function, substance synthesis and distribution”[38,39, and 40].“In the current study, regular fertilization of plants in split dosages using water soluble fertilizers may have supported adequate plant growth. Aside from the increased nutrient supply provided by substrates, notably daincha and vermicompost would have enhanced longer vine length and higher dry matter production in ribbed gourd. Daincha's proximate elements, such as ash, crude protein, and crude fibre, may have boosted the availability of nutrients in the growing media”[41,42].

“Once the available nutrients from media gradually decline from the crop's earliest stages, the application of fertiliser solution would provide the crop with the nutrients it requires” [43]. “Vermicompost may supply necessary nutrients for crop growth since it contains readily available nutrients such as nitrates, andexchangeable P, K, Ca, and Mg” [44]. “Some of these primary mineral types are transformed into soluble forms that plants can absorb [45]. The use of flyash improves the availability of nutrients such as Cu, Fe, Al, Si, P, S, K, Mg, and Ca. After the available nutrients from media gradually decline from initial stages of the crop, the application of fertilizer solution would supply the necessary nutrients to the crop is in accordance with the findings” of Shree *et al*. [45]. “Part of growing media containing vermicompost may provide essential nutrients for the growth of crop since the nutrients in vermicompost are present in readily available forms such as nitrates, exchangeable P, K, Ca, and Mg [44]. Some of these main mineral forms are converted into soluble forms which are used for plant uptake” [45]. “Application of flyash increases the availability of nutrients such as Cu, Fe, Al, Si, P, S, K, Mg, and Ca”, etc. [25]. In the present study the identified role of vermicompost and flyash has been utilized positively by including it as a component in all growing media tested.

a) Fruiting in growing media with CP+VC+GM+Sand

b) Fruiting in growing media with CP+VC+FA+Sand

c) Fruiting in growing media with CP+VC+Sand



d) Harvested fruits

Fig.5. View of ribbed gourd crop treatment wise at fruiting stage

3.5 Nutrient use efficiency

Nutrient use efficiency (Table 5) was computed in terms of response ratio, apparent nutrient recovery and physiological efficiency for the applied N, P, and K nutrients. The highest response ratio of N (78.11), P (834.8) and K (439.3) was recorded in the treatment having the combination of growing media containing coirpith: vermicompost: green manure: sand (T_3). The physiological efficiency of N varied from 350.1 to 356.7 and the variation was not significant. Physiological efficiency of P (3871), and K (246.3) was highest with growing media with coirpith: vermicompost: sand (T_1) while lowest physiological efficiency was noted in coirpith: vermicompost: green manure: sand (T_3) for P (3570) and in coirpith: vermicompost: fly ash: sand (T_2) for K (221.8). Apparent recovery was highest in the growing media with coirpith: vermicompost: green manure: sand (T_3) for N (22.42%), P (23.47 %), and K (192.9 %).

Table 5. Nutrient use efficiency, water use efficiency and benefit-cost ratio of ribbed gourd at harvest stage

T. No.	Response Ratio (kg yield / kg nutrient applied)			Physiological Efficiency kg yield / kg nutrient absorbed		
	N	P	K	N	P	K
CP+VC+S	64.00	683.9	359.9	356.7	3871	246.3
CP+VC+FA+S	73.73	787.9	414.6	355.4	3665	221.8
CP+VC+GM+S	78.11	834.8	439.3	350.1	3570	228.2
SEd	1.02	10.93	5.75	11.2	110.8	7.79
CD(P=0.05)	1.74**	18.62**	9.80**	NS	188.7*	13.27*

T. No.	Apparent Nutrient Recovery (%)			Harvest Index	Water use efficiency	
	N	P	K		kg fresh fruit mm^{-1}	g fresh fruit L^{-1}
CP+VC+S	18.02	17.71	146.7	0.289	336.9	33.7
CP+VC+FA+S	20.82	21.56	188.0	0.321	388.1	38.8
CP+VC+GM+S	22.42	23.47	192.9	0.308	411.2	41.1
SEd	0.66	0.51	4.89	0.0046**	5.38	0.54
CD(P=0.05)	1.12**	0.87**	8.32**	0.0078**	9.17**	0.92**

T. No.	Profit for cropping each container		
	Components of growing media	Net profit Profit Rs.	Benefit-Cost Ratio
T_1	CP+VC+S	301.91	1.50
T_2	CP+VC+FA+S	354.41	1.89
T_3	CP+VC+GM+S	378.06	1.95

According to the trend of yield obtained, the response ratio, harvest index, apparent nutrient recovery of N, P and K as well as water use efficiency were found. Apparent nutrient recovery recorded ranged from 18.02 to 22.42 per-cent for N,17.71 to 23.41 per-cent for P, and 146.7 to 192.9 per-cent for K. These recovery values indicated that in spite of efficient circulation of nutrients through irrigation water, only about 20 per cent of applied N, and P were recoverable by crop. The remaining N and P may be either retained in growing media or retained in irrigation water or lost. The loss may occur particularly for N as ammonia volatilization and denitrification. Extremely high efficiency indicated for K may be due to greater recovery of K by crop than the applied K, which may be related to the phenomenon of luxury consumption of K by crops. As substrates used in growing media containeda large amount of unbound K, more amount K would have been absorbed bythe crop.

3.5. Harvest Index and Water Productivity

The harvest index is an indication of the ability of the plant to divert the total drymatter to form the economic part. Comparably, avery high harvest index was realized in growing media containing Coirpith: Vermicompost: Fly ash in combination with sand (0.321) followed by coirpith: vermicompost: green manure: sand (T_3) (0.308).

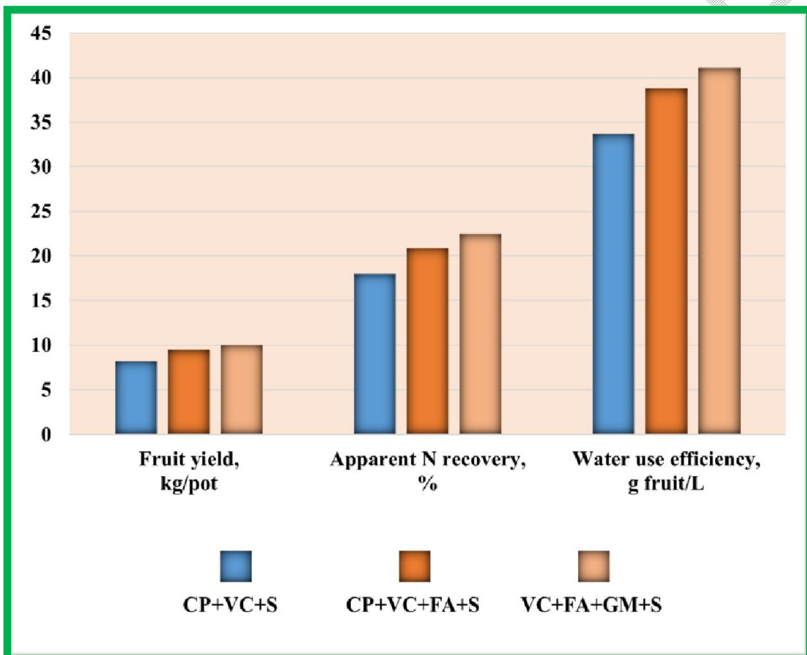


Fig.6. Fruit yield, Apparent N recovery and Water use efficiency in ribbed gourd pandal experiment

The water productivity computed as weight of fresh fruit produced per mm of consumed water was highest to the tune of 411.2 kg mm^{-1} in growing media containing Coirpith: Vermicompost: Green Manure: Sand (T_3) followed by in coirpith: vermicompost: fly ash: sand (T_2) (388.1 kg mm^{-1}) and coirpith: vermicompost: sand (T_1) (336.9 kg mm^{-1}) (Fig.6).

3.6. Benefit-Cost ratio

BC ratio computed for each container basis (Annexure A2) showed a promise to implement this kind of soilless culture for profitable crop production. Benefit-Cost ratio was highest (1.95) in growing media with coirpith: vermicompost: green manure: sand with a net profit of Rs. 378.06, which was followed by coirpith: vermicompost: fly ash: sand (1.89) with a net profit of Rs. 354.41 and coirpith: vermicompost: sand (1.50) with net profit of Rs. 301.91 per container. Accountable profitable results were obtained because of the simplicity of the method used for soilless culture and use of low-cost materials.

4 Conclusion

Based on the promising effects identified in previous experiment, thepresent validation experiment was conducted. The results confirmed that the growth, yield, and nutrient uptake were highest in growing media containing coirpith: vermicompost: green manure: sand, followed by coirpith: vermicompost: flyash: sand, and coirpith: vermicompost: sand. The salinity of raw substrates used in growing media was well reduced in thematric suction irrigation method as low-saline irrigation water was used for circulation. Limited usage of water for crop production has been achieved, which was evidenced by high values recorded in water productivity. Conclusively the exploitation of the potentiality of particulate organic materials has been well demonstrated in thesoilless system for growing crops in open waste land areas. This technique may be useful for farmers to generate additional farm income with proper use of particulate organic substrates obtainable/ available in their farm.However, researches are needed to continue this use this technique in large scale areas where there is lot of waste lands and utilize those waste lands for containerized crop production.

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CONFLICTS OF INTEREST

The authors confirm that there exists no conflict of interest.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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ANNEXURES

A1. Account of water consumed by ribbed gourd crop in matric suction irrigation (for 30 pots)

Pandal experiment			
DAS	**Date in year 2020-2021**	**Water dropped in tank in a week (cm)**	**Water consumed (L)**
7	10-Nov	19.1	121
14	17-Nov	22.4	142
21	24-Nov	22.6	143
28	01-Dec	26.2	166
35	08-Dec	28.3	180
42	15-Dec	40.3	257
49	22-Dec	46.1	293
56	29-Dec	57.9	368
63	05-Jan	77.0	490
70	12-Jan	85.9	546
77	19-Jan	97.6	621
84	26-Jan	92.1	586
91	02-Feb	87.4	556
98	09-Feb	102.9	654
105	16-Feb	110.8	705
112	23-Feb	111.3	708
119	01-Mar	122.7	780
Total water consumed (L)			7318

A2. Worksheet for calculating Benefit – Cost Ratio for cultivation of ribbed gourd in *Pandal* system under matric suction irrigation

Treatments	Fixed Cost	Working Cost (for a single growing media container)						
	Basic Cost (Container + Pandhal) (Rs.)	Cost of media (Rs.)	Cost Fertilization (Rs.)	Cost of Sowing (Rs.)	Cost of Plant Protection (Rs.)	Cost of Labour (Rs.)	land cost + Interest at 5%	Working cost (Rs.)
CP+VC+Sand	43.33	78.00	12.28	2.00	20.00	11.00	5.00	171.61
CP+VC+FA+Sand	43.33	66.25	12.28	2.00	20.00	11.00	5.00	159.86
CP+VC+GM+Sand	43.33	72.50	12.28	2.00	20.00	11.00	5.00	166.11

Working cost	Gross Cost (for a single growing media container)		
	Interest on WC at 10.5%	Managerial Cost @ 6.5%	Gross working Cost per Pot (Rs.)
171.61	18.02	11.15	200.78
159.86	16.78	10.39	187.03
166.11	17.44	10.80	194.34

Yield of fruits Pot^{-1}	Fruit selling cost/kg	Gross Profit per Pot (Rs.)	Fixed cost Repayment	Net Profit (Rs.)	B:C Ratio
8.22	42.00	345.24	43.33	301.91	1.50
9.47	42.00	397.74	43.33	354.41	1.89
10.03	42.00	421.39	43.33	378.06	1.95

Cost of pandal system for 30 containers (30 Poles): Rs. 50000/- (Life expectancy -50 years); Fixed Cost per season/ containerRs.33.33/-

Cost of Tub+container+tubing = Rs. 400/- ; Cost per season (life expectancy of 10 years (20 crops)) = Rs.10/-