Original Research Article

Impact of Phytoremediated Sewage Water and Organic Inputs on the Growth and Yield of Okra

Abstract

Okra belongs to family Malvaceae, it is a good source of nutrition as well as for farmer economy. This experiment was based ontwo years field work. During the year 2021-22 and 2022-23 it was aimed to study the Effect of phytoremediated sewage water irrigation, organic manures & biofertilizers on growth and yield of okra var. *Kashi chaman*in Prayagraj agro climatic condition. The experiment was designed as Randomized block design consist of 16 treatments and 3 replicates of each. Among which the treatment $T_{15}$with the combination of Azotobacter @4kg/ha + PSB(Pseudomonas) @2kg/ha +Vermicompost + treated sewage water, emerged as most effective in promoting highest Number of branches (4.61) number of leaves (28.52) leaf area LAI (124.12 cm^2)Root length per plant (15.15 cm)maximum fruit yield (464.72 g)was found significant at 0.05 level of critical difference.Whereas maximum plant height (127.11 cm) was recorded in T9 (Vermicompost+ Azotobacter @4kg/ha and TSW). So it can be concluded that this treatment combination can enhance plant growth and yield attributes of okra variety *Kashi chaman*along with sustaining nutrient levels in the soil.Ultimately, by applying these practices it offers an alternative way for resource-limited farmers to achieve long-term productivity.

Keywords: *Okra, Bio fertilizers, Organic manure, Kashi chaman.*

Introduction

Okra, scientifically known as *Abelmoschus esculentus* L., is a member of the Malvaceae family. It is referred to by various names such as Lady's finger, okra, bhindi, okura, quimgombo,bamia,gombo,dependingontheregion whereitisgrown **(Jain *et al.*, 2012)**. Okra is said to be originated fromAfrica and is grown in various countries acrossAfrica,Asia,SouthernEurope,andAmerica.Itthrivesintropical,subtropical,andwarm temperateclimates**(Durazzo*etal.*,2019)**. This particular crop is extensively grown for consumption and is recognized worldwide for its delicious taste **(Dhaliwal, 2010).** The extract fromthesepodsisoftenusedasathickeningagentinvarioussoupandsaucerecipestoincrease their thickness **(Kumar *et al.*, 2013)**. Polysaccharides found in okra have been utilized in sweetened frozen foods like ice creams and bakeryproducts.These compounds offer various health benefits and contribute to extending the shelf life of these food items **(Archana *et al.*, 2015)**.

In order to achieve success in utilizing treated wastewater for cropproduction,severalfactorsmustbecarefullyconsidered.Theseincludeselectingthemost suitablecrops,choosingappropriateirrigationmethods,andimplementingeffectivestrategies to maximize crop yields and qualitywhile also preservingsoil productivityand protectingthe environment. According to **Elnasikh and Satti (2017**) organic manures play a crucial role in improving soil structure and fertility, while biofertilizers have the abilityto increase nutrient availabilityand stimulatebeneficialmicrobialactivity**(YoussefandFarag,2021)**. Bio-fertilizers, on the other hand, are microorganisms with agricultural value.Theyhave the ability to convert nonstable components into usable forms through biological processes **(Kumar *et al.*, 2011)**.According to **Singh *et al.* (2014)**, a significant portion of conventional N-based fertilizers, up to 50%, is lost to the soil and environment. These activities have the potential to have a substantial impact on the environment, leading to increased levels of greenhouse gases, soil acidification, depletion of non-renewable resources, and the release of nitratesintogroundwaterandsurfacewater.Various research has been explored regarding combined effect of organic manure and biofertilizer on okra and other crops but less focused on the utilization of phytoremediated sewage water along with biofertilizers and organic manure. So, this research was attempted to analyse the combined effect of phytoremediated sewage water irrigation, organic manure and biofertilizer on growth and yield of okra.

Materials and methods

Geographicallocationoftheexperimentalsite: InPrayagraj,UttarPradesh211007, India,theinvestigationwascarriedoutintheresearch area of the Department of Biological Sciences at Sam Higginbottom UniversityofAgriculture, Technology and Sciences. The experimental field is located in close proximity to the Yamuna River, on the left side of the Allahabad-Rewa Road, and is roughly 8 kilometers from the metropolisofAllahabad.Thecoordinatesoftheexperimentalsiteare81.51°Elongitudeand25.57° Nlatitude.

SoilCharacteristicsoftheexperimentalsite:
Thesoilintheexperimentalfield,whichislocatedinthecentralGangeticalluviumregion, has a neutral pH level and is characterized by its depth. Soil samples were collected prior to sowing by using an auger at a depth of 15 cm. The composite samples were utilized for the purposeofconductingchemicalandmechanicalanalysis.Thesoilhadasandyloamtextureand containedlowlevelsoforganiccarbon.Ithadmediumlevelsofavailablenitrogen, phosphorus, andpotassium (Table no1)

Sewage water purification: For the purification of sewage water, phytoremediation technique was applied. In this experiment, *Ecchornia crassipes* used as green plant for phytoremediation of sewage water. After 21 days of treatment various physico-chemical parameters of water such as pH, Dissolved oxygen, Biological oxygen demand, Turbidity, Electrical conductivity etc.wasanalysed and the result obtained was compared with the standard value determined by Food and agricultural organization (FAO) for the safe use of wastewater for irrigation purpose.

Crop and Experimental Details: The studywas designed using a randomized block design with fifteen treatments and threereplications,anditranfromJanuarytoJune(2021–22&2022-23). Crop selected was okra (*Abelmoschus esculentus L. Moench*) family Malvaceae, Variety Kashi chaman. The plants were strategically spaced at a distance of Plant to Plant and row to row 60cm× 45cm.Total 432 plants and experimental area of 57.6 m^2.The treatment combinations consisted of alternatives such as the Vermicompost- @2.5 t/ ha (per plot 600g), Azotobacter- @4 kg/ ha (per plant: 1.20g),PSB- @2 kg/ ha (per plant:0.50g),Quantity of sewage water – 168 litre per irrigation taken under study as shown in Table 2.The treated sewage water which was used in the experiment was firstly treated with *Ecchornia crassipes* for 21 days after that applied in the form of irrigation.

Sampling and parameters: studied Growth attributes are observed under various parameters like – plant height (cm), number of branches per plant, number of leaves per plant, root length per Plant (cm), number of nodes at first flowering, leaf area, leaf area index. Similarly yield attributes are - days to first fruit harvest, number of pods per plant, pod length (cm), pod diameter (mm), average fresh pod weight (g), total fruit yield per plant (g).

Statistical analysis: The experiment was organized in a Randomized block design manner with three replicates of each treatment during two years 2021-2022 and 2022-2023. Statistical analysis was done to determine the interdependencies between different variables the collected data were submitted to two way analysis of variance (ANOVA) approach were compared at the 0.05 level. An open source agricultural data analysis tool i.e. OPSTAT was used for statistical analysis.The data incorporated in the tables are based on the pooled data of both the years.

Table 1. Physical and chemical properties of experimental soil:

Sl. No.	Particulars	Values (2021-22)	Values (2022-23)	Methodemployed
I	**PhysicalProperties**			
	Sand(%)	60.41	60.38	BouyoucosHydrometermethod**(Piper,1966)**
	Clay(%)	22.89	22.93	
	Silt (%)	16.35	16.36	
	Texture	Sandy loam	Sandy loam	**USDATriangle,SoilSurvey, 1975**
II	**Chemicalproperties**			
	pH	7.2	7.3	GlassElectrode,pH meter, **(Jackson,1967)**
	Electrical conductivity(dS/m)	0.26	0.28	Conductivitybridge**(Piper, 1966)**
	Organiccarbon(%)	0.48	0.49	Wetmethod,**(Walkley,1947and Black 1965)**
III	**AvailableNutrients**			

	AvailableNitrogen (kg/ha)	171.48	173.54	Modifiedkjeldhal's method **(Jackson,1967)**
	AvailablePhosphorus (kg/ha)	13.6	15.41	Olsensmethod**(Muhr*etal*., 1963)**
	AvailablePotassium (kg/ha)	215.4	218.34	Flamephotometermethod **(Muhr*etal*., 1963)**

Table 2. Details of treatment combinations:

S.No.	Notation	Treatmentcombinations
1	**T0**	Control
2	**T1**	Treatedsewagewater
3	**T2**	Vermicompost+Normal water
4	**T3**	Vermicompost+Treatedsewagewater
5	**T4**	Azotobacter@4kg/ha+Normal water
6	**T5**	Azotobacter@4kg/ha+treatedsewagewater
7	**T6**	PSB(Pseudomonas)@2kg/ha +Normal water
8	**T7**	PSB(Pseudomonas)@2kg/ha +treatedsewage water
9	**T8**	Vermicompost+Azotobacter@4kg/ha+Normal water
10	**T9**	Vermicompost+Azotobacter@4kg/ha+treatedsewage water
11	**T10**	Vermicompost+PSB(Pseudomonas)@2kg/ha+Normal water
12	**T11**	Vermicompost+PSB(Pseudomonas)@2kg/ha+treatedsewageWater
13	**T12**	Azotobacter@4kg/ha+PSB(Pseudomonas)@2kg/ha+Normal Water
14	**T13**	Azotobacter@4kg/ha+PSB(Pseudomonas)@2kg/ha+ treated sewagewater
15	**T14**	Azotobacter@4kg/ha+PSB(Pseudomonas)@2kg/ha+Vermicompost+Normal water
16	**T15**	Azotobacter@4kg/ha+PSB(Pseudomonas)@2kg/ha +Vermicompost+treatedsewagewater

Results and discussion:-

Growth attributes of okra

According to observation recorded it was resulted that the treatment T15 with the combination of Azotobacter @4kg/ha + PSB(Pseudomonas) @2kg/ha +Vermicompost + treated sewage water shows the significant result at 0.05 level of critical difference. The maximum growth attributes based on pooled data that includes number of branches per plant (4.61) number of leaves per plant (28.52) leaf area (124.12) leaf area index (1.11) Number of nodes at first flowering (6.55) Root length per plant (15.15cm)whereas maximum plant height (127.11 cm) was recorded in T9.Over all treatments during both the years of experiment as shown in Table 3-4.Whereas lowest growth attributes was recorded in T_0 [Control].

The application of plant nutrients through organic sources likes vermicompost, farm yard manure and bio fertilizers remain the alternative choice of the growers for maintaining its sustainable production **(Gayathri and Reddy, 2013).** Vermicompost may have enhanced the microbial activity in the soil, leading to benefits such as improved oxygen availability, optimal soil temperature, increased soil porosity and water infiltration, enhanced nutrient content, and ultimately, increased plant height **(Arora et al., 2011).**

Bio- inoculants such as Azotobacter and PSB have been found to enhance the bio-availability of Nitrogen and Phosphorous in the soil through fixation by converting non-usable form into usable form, as demonstrated in studies by **Zaidi et al. (2009)** and **Hafez et al. (2016).** Pseudomonas can help to overcome the negative effects of contaminated waters, and other environmental and biological stresses, as described by **Gardezi et al. (2019).**

In addition, the consistent supply of water and nutrients through treated sewage water irrigation guarantees that the plants have the necessary resources to maintain robust growth and branch development all year round **(Khan, 2018).**

Yield attributes of okra

A similar trend has been observed on various yield attributes. There was a significant effect of yield attributes at 0.05 level of critical difference. In the continuation the treatment T_{15}also recorded maximum daystofirstfruit harvest (39.36) Number of pods per plant (22.86) Pod length (14.32cm) Pod diameter (13.51mm) Average fresh pod weight (20.50g) Total fruit yield per plant (464.72 g)based on the pooled data of both years as depicted in Table 5.

In addition, vermicompost promotes mutually beneficial interactions between plants and beneficial soil microorganisms, such as mycorrhizal fungi. These microorganisms play a vital role in improving nutrient absorption and transportation within the plant. These interactions contribute to enhanced nutrient absorption and distribution towards reproductive organs, leading to a notable increase in the length of okra pods **(Rehman et al., 2023).**

Azotobacter, a bacterium that fixes nitrogen, has the ability to improve nitrogen availability. This, in turn, promotes the growth of plants and their reproductive processes, leading to an increase in flower and fruits (pods) production. In addition, PSB has the ability to solubilize insoluble phosphorus, allowing plants to access this crucial nutrient for seed development and maturation **(Iftikhar et al., 2024).**

According to **Hashem and Qi (2021**), treated sewage water can provide vital macro and micronutrients that support both vegetative and reproductive growth. Vermicompost enhances the soil by adding organic matter, resulting in improved soil structure, increased water retention, and enhanced nutrient availability. These benefits have a positive effect on the development of flowers and pods, as demonstrated by **Rehman et al. (2023).**

Conclusion

In view of two years of experimental investigation it was found that phytoremediation of sewage water with *Ecchornia crassipes* improves the physico- chemical characteristics of sewage water and found suitable for okra production in sandy loam soil.

Growth parameters including Number of branches, number of leaves, leaf area LAI was found maximum in T15 [Azotobacter @4kg/ha + PSB(Pseudomonas) @2kg/ha + Vermicompost + treated sewage water] whereas maximum plant height was recorded in T9 (Vermicompost+ Azotobacter @4kg/ha and TSW) and T15 treatment combination resulted in maximum fruit yield (464.72g) and other yield parameters.So, overallit can be concluded that the T15 (Azotobacter @4kg/ha + PSB(Pseudomonas) @2kg/ha + Vermicompost + treated sewage water) had found most effective in terms of growth and yield of okra among all the treatments.Based on the tolerance capacity of other crops relative to stress, this particular treatment combination can be used for their better productivity as per the adequate fertilizer application mention by ICAR.

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 the writing or editing of this manuscript.

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Table 3. Effect of Phyto remediated sewage water irrigation, organic manures, and biofertilizers on growth attributes of okra var. Kashi chaman.

TreatmentSymbol	Plantheight(cm)			Numberofbranchesperplant			Numberofleavesperplant		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T0	10.12	35.19	72.98	0.81	2.51	3.53	6.33	11.68	19.73
T1	10.87	37.85	79.63	0.92	2.65	3.76	6.63	12.17	20.34
T2	15.63	44.40	109.11	1.03	2.96	4.28	7.91	14.57	24.10
T3	17.88	48.36	114.76	1.54	3.13	4.32	8.35	15.12	26.30
T4	11.72	40.56	85.28	1.07	2.71	3.85	6.95	12.85	21.18
T5	12.84	42.70	88.57	1.19	2.78	3.91	7.19	13.14	21.83
T6	12.30	40.59	85.22	1.11	2.75	3.89	6.95	12.85	21.18
T7	13.39	42.32	90.94	1.15	2.78	3.94	7.19	13.32	22.23
T8	16.48	53.26	107.95	1.44	3.05	4.21	8.03	14.84	25.18
T9	20.12	58.78	127.11	1.79	3.32	4.58	8.68	15.70	27.20
T10	17.03	53.24	110.37	1.62	3.22	4.21	8.15	14.84	25.17
T11	19.27	56.00	120.40	1.66	3.24	4.44	8.68	15.70	27.20
T12	14.24	46.40	99.15	1.34	2.86	4.06	7.58	13.94	23.19
T13	14.78	50.52	99.48	1.30	2.88	4.06	7.58	13.93	23.18
T14	18.73	56.01	120.21	1.69	3.25	4.44	9.02	15.26	28.13
T15	20.06	58.75	127.05	1.83	3.35	4.61	9.14	15.44	28.52
F-test	S	S	S	S	S	S	S	S	S
S.E.(m)(±)	0.17	0.38	0.86	0.02	0.01	0.01	0.05	0.07	0.19
C.D.(P=0.05)	0.47	1.09	2.44	0.05	0.03	0.04	0.14	0.21	0.58

Table 4. Effect of Phyto remediated sewage water irrigation, organic manures, and biofertilizers on growth attributes of okra var. Kashi chaman.

Treatment symbol	Leaf area			Leaf area index			Number of nodes at first flowering	Rootlengthperplant(cm)
	20 days	40	60 days	20 days	40	60 days		
T0	15.69	31.20	56.88	0.13	0.26	0.47	6.01	12.59
T1	16.55	33.49	62.80	0.14	0.28	0.52	6.04	12.73
T2	23.62	47.12	91.91	0.20	0.39	0.77	6.28	13.95
T3	26.83	53.40	106.60	0.22	0.45	0.89	6.42	14.44
T4	17.72	35.79	68.73	0.15	0.30	0.57	6.11	13.02
T5	19.45	39.16	74.40	0.16	0.33	0.62	6.16	13.17
T6	18.58	37.47	71.56	0.15	0.31	0.60	6.13	13.02
T7	20.40	40.84	77.23	0.17	0.34	0.64	6.16	13.27
T8	24.80	49.42	97.84	0.21	0.41	0.82	6.35	14.13
T9	28.02	55.69	112.53	0.24	0.46	1.02	6.47	14.73
T10	25.66	51.10	100.67	0.21	0.43	0.84	6.35	14.13
T11	28.88	57.38	115.36	0.24	0.48	0.96	6.47	14.73
T12	21.59	43.14	83.16	0.18	0.36	0.69	6.23	13.68
T13	22.45	44.82	85.99	0.19	0.37	0.72	6.23	13.68
T14	30.05	59.67	121.29	0.25	0.50	1.04	6.53	15.04

T15	30.91	61.36	124.12	0.26	0.51	1.11	6.55	15.15
F-test	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
S.E.(m)(±)	0.24	0.47	0.94	0.01	0.02	0.03	0.01	0.04
C.D.(P=0.05)	0.69	1.33	2.65	0.03	0.05	0.10	0.03	0.12

Table 5. Effect of Phyto remediated sewage water irrigation, organic manures, and biofertilizers on yield attributes of okra var. Kashi chaman.

Treatment Symbol	Daystofirst fruit harvest	Numberof podsperplant	Podlength (cm)	Poddiameter(mm)	Average freshpodweight(g)	Total fruit yield per plant (g)
T0	46.61	16.66	11.20	11.11	13.98	245.70
T1	46.15	17.83	11.48	11.34	14.94	266.38
T2	41.45	19.73	12.89	12.35	15.05	296.94
T3	42.66	19.17	13.56	12.89	14.17	271.57
T4	45.30	18.45	11.85	11.57	15.49	285.79
T5	44.59	19.24	12.11	11.73	15.81	304.18
T6	45.31	18.77	11.85	11.65	17.10	320.88
T7	44.60	17.65	12.05	11.81	17.54	309.58
T8	41.88	21.25	13.22	12.58	18.11	384.73
T9	39.01	21.69	14.43	13.12	19.31	418.63
T10	41.89	19.64	12.53	12.66	18.18	356.87
T11	40.20	21.52	13.22	13.20	18.64	401.03
T12	43.57	18.82	13.90	12.04	19.60	388.37
T13	43.58	19.27	12.53	12.12	19.46	391.14
T14	40.02	22.23	13.91	13.43	20.37	441.52
T15	39.36	22.86	14.32	13.51	20.50	464.72
F-test	S	S	S	S	S	S
S.E.(m)(±)	0.18	0.18	0.05	0.04	0.01	0.30
C.D.(P=0.05)	0.54	0.54	0.14	0.11	0.03	0.89