DEVELOPMENT AND EVALUATION OF AGRO RESIDUE BASED BIODEGRADABLE POTS AND POTTING MEDIA FOR HORTICULTURAL APPLICATIONS

PRATIBHA

CENTRE FOR RURAL DEVELOPMENT AND TECHNOLOGY

INDIAN INSTITUTE OF TECHNOLOGY DELHI

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by

PRATIBHA

CENTRE FOR RURAL DEVELOPMENT AND TECHNOLOGY

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CERTIFICATE

This is to certify that the thesis entitled **“Development and evaluation of agro residue based biodegradable pots and potting media for horticultural applications”,** being submitted by **Mrs. Pratibha** to the **Indian Institute of Technology Delhi** for the award of **“Doctor of Philosphy”** is a record of bonafide research work carried out by her. She has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis. To the best of our knowledge, the results contained in this thesis have not been submitted in part or full to any other university or institute for the award of any degree or diploma.

Dr. Hariprasad P.
Associate Professor
Centre for Rural Development and Technology
Indian Institute of Technolgy Delhi
New Delhi – 110016

Dr. Sampa Saha
Associate Professor
Department of Materials Science and Engineering
Indian Institute of Technolgy Delhi
New Delhi - 110016

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Pratibha

Pratibha

ABSTRACT

The present study aims to develop a new route of paddy straw (PS) utilization in horticulture. In the first half of the study, we aimed to develop PS-based biocomposites (PS-BC) and their use in developing pots for horticultural applications. Six different BCs were developed using PS (treated/untreated) as filler, corn starch (native/cross-linked) and glycerol as matrix and plasticizer, respectively. BC4 had recorded the highest mechanical strength (6.82 MPa tensile strength), followed by BC3 > BC6 > BC5 > BC2 > BC1. Among them, the highest density (2.83 g/cm^3) and least porosity (31.03%) were recorded by BC4. None of the BCs was found to be antimicrobial in nature. Soil burial tests under field conditions recorded a maximum weight loss of 79.32% in 20 days for BC1, indicating higher susceptibility for degradation. Whereas BC4 (57.43%), BC5 (60.30%), and BC6 (60.48%) marked the least weight loss in the same burial period, which were comparatively resistant to degradation. Fourier transform infrared spectroscopy (FTIR) indicated a diminished peak corresponding to the –OH group revealing their susceptibility to microbial degradation. These BCs were moulded into pots and tested with standard potting mixture and cucumber seedlings under greenhouse and field conditions. Under greenhouse conditions, 4 BCs (BC3, BC4, BC5, and BC6) pots were found physically stable up to 28 - 30 days, and the growth parameters of the test plant were normal. By considering the ease of preparation, BC3 and BC4 were used for field testing. It was shown that water loss through the walls of the BC3 and BC4 pots was up to 47 and 44%, respectively, compared to the plastic pot (0.72%). Upon transplantation into the field, the disintegration of the BCs and penetration of the developing roots out of the pots without affecting the normal growth of the plant were observed. The cost analysis of BC3 pots was found to be in the range of 3-4 Rs./pot. The pot making technology was demonstrated to farmers by organizing a workshop at the village level, and pots were distributed for testing at fields. Most of the farmers were satisfied with the pot performance, and some of them even showed interest in the pot making technology as an income-generating activity. In the second half of the study, the potential of PS (in different volumes) and six de-oiled cakes (DOCs) (2.50, 5, 7.50 and 10% (v/v)) as potting media (PM) amendments were studied. Further, its subsequent effect on the physical and nutritional properties of the PM and plant (cucumber (*Cucumis sativus* L.) and tomato (*Solanum lycopersicum* L.)) growth were analyzed. Among 6 DOCs tested, neem (2.50%) and niger cake (5%) were found to improve the plant growth of both crops. Further, PS powder amendment to selected PM improved the plant growth, up to 10% (v/v). Beyond that, there was a significant growth reduction observed in terms of root length (RL), shoot length (SL), fresh weight (FW), dry weight (DW), leaf area (LA) and seedling vigour index (SVI). Two optimized potting media, Developed potting media -1 (DPM-1) (Coir pith+Vermicompost+Neem cake+PS:77.50+10+2.50+10% (v/v)) and Developed potting media-2 (DPM-2) (Coirpith+Vermicompost+Niger cake+PS:75+10+5+10% (v/v)) were evaluated in comparison to peat-based two commercial potting media (CPM-1 and CPM-2). DPM-1 and DPM-2 recorded, bulk density (0.29 and 0.28 g/cm^3), water holding capacity (59.87 and 59.02%), air porosity (23.50 and 25.61%), total porosity (83.37 and 84.63%), electrical conductivity (2.64 and 2.76 mS/cm), and pH (6.56 and 6.40), respectively. However, all these parameters were within the recommended range of ideal PM. Tomato and cucumber seedlings grown in both DPMs showed significant improvement in growth and accumulation of macro and micronutrients compared to CPMs and control. The cost of DPM-1 and DPM-2 was calculated as around 13 and 22 Rs/kg, respectively. After testing DPMs at local nurseries, the owners were satisfied with their performance and have shown willingness to develop the same if the technology is available or purchase if DPMs are available in the market. By analyzing the results obtained from the present study and data collected from the survey, it could be concluded that the PS is a potential source to use in the horticulture sector as a replacement to plastic pots and PM by employing the methodology developed. Also, the study opened a new avenue to develop PS based small scale industries at the rural level, which empowers the rural economy.

सार

वर्तमान अध्ययन का उद्देश्य बागवानी में धान की पराली (पीएस) के उपयोग का एक नया मार्ग विकसित करना है। अध्ययन के पहले भाग में, हमने पीएस-आधारित बायोकंपोजिट्स (पीएस-बीसी) विकसित करने और बागवानी अनुप्रयोगों के लिए पॉट्स को बनाने में उनके उपयोग का लक्ष्य रखा। पीएस (उपचारित /अनुपचारित) को भराव, कॉर्न स्टार्च (देशी/क्रॉस-लिंक्ड) और ग्लिसरॉल को क्रमशः मैट्रिक्स और प्लास्टिसाइज़र के रूप में उपयोग करके छह अलग-अलग बीसी विकसित किए गए थे। BC4 ने उच्चतम यांत्रिक शक्ति (6.82 MPa तन्य शक्ति) दर्ज की थी, उसके बाद BC3> BC6> BC5> BC2> BC1 का स्थान था। उनमें से, बीसी4 ने उच्चतम घनत्व (2.83 ग्राम/सेमी^{3}) और न्यूनतम सरंध्रता (31.03%) दर्ज की थी। कोई भी बीसी प्रकृति में रोगाणुरोधी नहीं पाया गया। खेत की परिस्थितियों में मृदा दफन परीक्षणों ने बीसी1 के लिए 20 दिनों में अधिकतम वजन (79.32%) क्षति दर्ज किया था, जो गिरावट के लिए इसकी उच्च संवेदनशीलता को दर्शाता है। जबकि BC4 (57.43%), BC5 (60.30%), और BC6 (60.48%) ने एक ही दफन अवधि में सबसे कम वजन घटाने को चिह्नित किया, जो तुलनात्मक रूप से गिरावट के प्रतिरोधी थे। फूरियर ट्रांसफॉर्म इंफ्रारेड स्पेक्ट्रोस्कोपी (FTIR) ने -OH समूह के अनुरूप शिखर को कम होने का संकेत दिया, जिससे माइक्रोबियल गिरावट के लिए उनकी संवेदनशीलता का पता चलता है। इन बीसी को पॉट्स में ढाला गया और ग्रीनहाउस और खेत की परिस्थितियों में मानक पॉटिंग मिश्रण और खीरे के पौधों के साथ परीक्षण किया गया। ग्रीनहाउस परिस्थितियों में, 4 BC (BC3, BC4, BC5, और BC6) पॉट्स, 28 - 30 दिनों तक भौतिक रूप से स्थिर पाए गए, और परीक्षण पौधों के विकास पैरामीटर सामान्य थे। तैयारी में आसानी को ध्यान में रखते हुए, BC3 और BC4 का उपयोग क्षेत्र परीक्षण के लिए किया गया था। यह देखा गया था कि प्लास्टिक के पॉट्स (0.72%) की तुलना में BC3 और BC4 पॉट्स की दीवारों के माध्यम से पानी की कमी क्रमशः 47 और 44% तक थी। खेत में प्रत्यारोपण करने पर, बीसी का विघटन और पौधे की सामान्य वृद्धि को प्रभावित किए बिना पॉट्स से विकासशील जड़ों का प्रवेश देखा गया। BC3 पॉट्स का लागत विश्लेषण 3-4 रुपये/पॉट की सीमा में पाया गया। ग्राम स्तर पर कार्यशाला आयोजित कर पॉट्स बनाने की तकनीक का प्रदर्शन किसानों को किया गया और खेतों में परीक्षण के लिए कुछ पॉट्स बांटे गए थे। अधिकांश किसान पॉट्स के प्रदर्शन से संतुष्ट थे, और उनमें से कुछ इस तकनीक को आय के साधन के रूप में अपनाने के लिए भी इच्छुक थे। अध्ययन के दूसरे भाग में, पराली (विभिन्न मात्राओं में) और छह डी-ऑयल केक (डीओसी) (2.50, 5, 7.50 और 10% (v/v)) की पोटिंग मीडिया (पीएम) संशोधनों के रूप में क्षमता का अध्ययन किया गया था। इसके अलावा, पीएम के भौतिक और पोषण गुणों और पौधों (खीरा (कुकुमिस सैटिवस एल.) और टमाटर (सोलनम लाइकोपर्सिकम एल.)) के विकास पर इसके प्रभाव का विश्लेषण किया गया। परीक्षण किए गए 6 डीओसी में, नीम (2.50%) और नाइजर केक (5%) दोनों

फसलों के पौधों की वृद्धि में सुधार करने के लिए पाए गए। इसके अलावा, चयनित पीएम में पीएस पाउडर संशोधन (10% (v/v)) से पौधे की वृद्धि में सुधार हुआ। इस मात्रा से ज्यादा उपयोग करने पर, जड़ की लंबाई (RL), तने की लंबाई (SL), ताजा वजन (FW), शुष्क वजन (DW), पत्ती क्षेत्र (LA) और अंकुर शक्ति सूचकांक (SVI) के संदर्भ में वृद्धि में महत्वपूर्ण कमी देखी गई। दो अनुकूलित पोटिंग मीडिया, विकसित पोटिंग मीडिया -1 (डीपीएम -1) (कॉयर पिथ+वर्मीकम्पोस्ट+नीम केक+पीएस: 77.50+10+2.50+10% (v / v)) और विकसित पोटिंग मीडिया -2 (डीपीएम -2)) (कॉयरपीथ+वर्मीकम्पोस्ट+नाइजर केक+पीएस:75+10+5+10% (v/v)) का मूल्यांकन पीट-आधारित दो वाणिज्यिक पोटिंग मीडिया (सीपीएम-1 और सीपीएम-2) की तुलना में किया गया था। डीपीएम -1 और डीपीएम -2 ने क्रमशः थोक घनत्व (0.29 और 0.28 ग्राम/सेमी^{3}), जल धारण क्षमता (59.87 और 59.02%), वायु सरंध्रता (23.50 और 25.61%), कुल सरंध्रता (83.37 और 84.63%), विद्युत चालकता (२.६४ और २.७६ mS/cm), और पीएच (6.56 और 6.40), दर्ज की थी। हालांकि, ये सभी पैरामीटर आदर्श पीएम की अनुशंसित सीमा के भीतर थे। दोनों डीपीएम में उगाए गए टमाटर और खीरे के पौधों ने सीपीएम और नियंत्रण की तुलना में वृद्धि और मैक्रो और सूक्ष्म पोषक तत्वों के संचय में महत्वपूर्ण सुधार दिखाया। DPM-1 और DPM-2 की लागत की गणना क्रमशः लगभग 13 और 22 रुपये/किलोग्राम के रूप में की गई थी। स्थानीय नर्सरी में डीपीएम का परीक्षण करने के बाद, मालिक अपने प्रदर्शन से संतुष्ट थे और अगर तकनीक उपलब्ध है या बाजार में डीपीएम उपलब्ध हैं तो इसे अपनाने की इच्छा दिखाई थी। वर्तमान अध्ययन से प्राप्त परिणामों और सर्वेक्षण से एकत्र किए गए आंकड़ों का विश्लेषण करके, यह निष्कर्ष निकाला जा सकता है कि विकसित पद्धति को अपनाकर पराली बागवानी क्षेत्र में प्लास्टिक के बर्तनों और पीएम के प्रतिस्थापन के रूप में उपयोग करने के लिए एक संभावित स्रोत है। साथ ही, अध्ययन ने ग्रामीण स्तर पर पीएस आधारित लघु उद्योगों को विकसित करने के लिए एक नया मार्ग खोला, जो ग्रामीण अर्थव्यवस्था को सशक्त बनाता है।

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LIST OF ABBREVIATIONS

Symbol	Full Name
%	Percentage
°C	degree Celsius
µ	Micro
µg	Microgram
µL	Microlitre
µm	Micrometre
µS/cm	Microsiemens Per Centimeter
3 D	3 Dimensional
AIR	Agro industrial residue
approx.	Approximately
ATP	Adenosine triphosphate
B	Boron
BA	Boric acid
BC	Biocomposite
C	Carbon
C/N	Carbon and nitrogen
Ca	Calcium
CEC	Cation Exchange Capacity
cfu	Colony forming units
CHN	Carbon hydrogen and nitrogen
cm	Centimetre
cmol/kg	Centimoles per kilogram
CO_2	Carbon dioxide
Co-DOC	Cotton de-oiled cake
conc.	Concentration
CP	Coir pith
CPM	Commercial potting media
CRF	Central Research Facility
Cu	Copper

DOC	Deoiled cake
DPM	Developed potting media
dS/m	deciSiemens per metre
DW	Dry weight
Eq.	Equation
Fe	Iron
FTIR	Fourier-transform infrared spectroscopy
FW	Fresh weight
g	Gram
GHG	Greenhouse gas
Gn-DOC	Groundnut de-oiled cake
h	Hour
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulfuric acid
ha	Hectare
HCl	Hydrochloric acid
IC_{50}	Half maximal inhibitory concentration
ICPMS	Inductively coupled plasma spectrometry
INR	Indian Rupee
K	Potassium
kg	Kilogram
kN	Kilonewton
KOH	Potassium hydroxide
kV	Kilovolt
L	Litre
LA	Leaf area
M	Molar
meq/L	Milliequivalents per litre
mg	Milligram
Mg	Magnesium
MGGP	Mahatama Gandhi Gramodaya Parisar
Mha	Million hectare

min	Minute
mL	Millilitre
mM	Millimolar
mm	Millimetre
MMT	Million metric tons
Mn	Manganese
Mo	Molybdenum
mol	Moles
MPa	Megapascal
mS/cm	MilliSiemens per centimeter
MT	Metric tons
Mu-DOC	Mustard de-oiled cake
MW	Megawatt
N	Normal
N	Nitrogen
NADPH	Nicotinamide adenine dinucleotide phosphate
NaOH	Sodium hydroxide
Ne-DOC	Neem de-oiled cake
Ni-DOC	Niger de-oiled cake
nm	Nanometre
NRF	Nano Research Facility
P	Phosphorus
PM	Potting media
PS	Paddy straw
psi	Pound per square inch
RL	Root length
rpm	Revolutions per minute
Rs	Rupee
SAIF	Sophisticated Analytical Instrument Facility
sec	Seconds
Se-DOC	Sesame de-oiled cake
SEM	Scanning electron microscope

Si	Silica
SL	Shoot length
SVI	Seedling vigour index
UV	Ultraviolet
v/v	Volume by volume
VC	Vermicompost
W	Watt
w/v	Weight by volume
w/w	Weight by weight
WHC	Water holding capacity
Zn	Zinc