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Research Article

Reverse Logistics: An Empirical Study for Operational Framework

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Abstract: This paper presents framework of reverse logistics optimizing the stakeholders' gain, social gain, economic gain and environmental gain. It identifes the roadblocks that prevail in recycling industry and describes various types of returns and wastes. Framework of the reverse logistics is evolved on the basis of actual happening of the items shown in table 1-4 disposed off from industries shown in table 6. The rejected items require environmental disposal passing through the different phases described in fow of operational framework. An operational framework of reverse logistics is developed studying fifty organizations.. In addition three best practices of reverse logistics are proposed by consolidating the experiential information and rich hands on industrial experience in supply chain and reverse logistics area. The research has proposed the Social, Stakeholder, Economic & Environmental (SSEE) sustained gain model optimizing the benefts of stakeholders and highlights the variety of waste and its operational methodology in Pakistani industry. The proposed framework does not include the hospital waste, radioactive waste, hazardous materials waste, municipal waste, agricultural waste and cold chain waste like meat, milk, etc.The operational framework is existing way of doing that takes the waste materials from point of origin to the point of recycling. A better understanding of this framework may help researchers and front line managers to develop better, more accurate models for effective and sustainable utilization of waste materials, benefting organizations and society by simultaneously enhancing the cost effectiveness and improving environmental awareness. The paper provides an operational framework of reverse logistics and 2S2E sustained gain model. Specifc applications are examined through empirical research.

Keywords: Reverse logistics, supply chain management, operational framework, recycling

1. INTRODUCTION

In the era of information technology where the whole world is connected and going to concentrate on one point market the whole Globe. Rising populations, globalization policies, fuctuating currency exchange rate, oscillatory behaviour of prices of world commodities and WTO regulatory requirements are threatening more and more. Intensive competition among manufacturers is increasing day by day and encouraging them to explore the innovative options for waste materials.

Increased environmental awareness and upcoming stringent environmental laws exert the pressures on manufactures to dispose off waste materials in an environmental friendly way otherwise the high pollution charge and closure of the manufacturing units will be the destiny. Returns whether they are manufacturing or distribution or customer they always have a potential for cost recovery and there is a way to reclaim the material to capture the monetary benefts [1]. Reverse Logistics deals with the fow of materials from point of consumption to the point of origin to recapture value or to ensure disposal [14].

As per the council of Logistics Management, "Reverse Logistics is the process of planning, implementing and controlling the effcient, cost-effective fow of raw materials, in-process inventory,

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fnished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal". Reverse Logistics can be defned as reverse process of logistics [2]. Reverse Logistics aims at the backward fow of material which starts from consumer to the producer and defectives appearing during the manufacturing process with a goal of maximizing value from items which require proper disposal [6]. Reverse Logistics programs and its effective implementation affects the bottom-line and boost the productivity. [17] Reverse logistics starts where formal supply chain ends. It starts from the consumer instead of supplier in the forward fow. Environmental friendly disposal, monetary returns to parties involved are the part of green logistics and require focus and attention of Life cycle assessment [8] this is the result of conscious efforts from Industrial Waste Contactor and the company itself to build the company image in society and provide a confdence to environmental protection agency.

2. LITERATURE REVIEW

Logistics is the vast feld. In supply Chain context, logistics deals with fow of materials, equipments, and people from point of origin to the point of destination. A fow associated from the supplier's supplier to customer's customers is regarded as forward fow. But there are sometime returns of any form that require backward fow of materials that is reverse logistics. In early nineties, the council of logistics management has published two books on reverse logistics. The frst by Stock [9] recognized the feld of reverse logistics as being relevant for business and society in general. One year later Kopicki et al. [12] paid attention to the discipline and practice of reverse logistics, pointing out opportunities on reuse and recycling. Kostecki [12] discusses the marketing aspects of reuse and extended product life. Stock [10] reports in detail how to set up and how to carry out reverse logistics programs. In literature there are many models which are developed on the basis of Liner programming for multi-items and multi-locations [2]. The structure of the Operational Framework of Reverse Logistics is not restricted to any item or any site or any party. The beauty of this framework is it involves all the operational stakeholders and ends up with Social, Stakeholder, Economic and Environmental (SSEE) gain model optimizing their gains. To understand the effective operation of this framework we must explore the impediments which create hurdles.

3. ROAD BLOCKS FOR REVERSE LOGISTICS

3.1 Lack of Awareness about Reverse Logistics

Impact of the reverse logistics is implicit in nature. Customers have greater value for the product in the local as well in the global markets. That is the reason focus towards the by product, scrap and rejected materials is less and it has a great potential to recover the money back.

3.2 Lack of Technical Expertise

Reverse logistics is the forgotten dimension. There is no formal education center that educates and guides how to play in the feld of reverse logistics. Mostly people involved in this business are uneducated and non-technical. They have learned the recycling techniques over the period of years and doing the businesses on the basis of experience and creativity. That discipline has a lot of entrepreneurial potential and there is lot of room that educated people may opt this feld as source of income.

3.3 Inconsistent Quality of Rejected Materials

Production of waste and nature of rejections are highly unpredictable. No one can indicate the nature of waste generated. In some cases like defective cartons or poly flm or confectionary waste or biscuit crumb or rotten potatoes a slight idea of quality can be conceived but most of the cases it is highly inconsistent the quality of defectives and rejections. So accordingly every time you will have to explore recycling techniques accordingly.

3.4 Financial Constraints

People in the business of reverse logistics can work either as a local waste contractor or Industrial waste contractor. To be the industrial waste contractor, one requires a strong fnancial muscle to make the payments on cash at the time of lifting the rejected material. Unless one knows about the fate of the rejected material the lifting may ruin or destroy his/her whole business.

3.5 Management Inattention

Due to green logistics and industrial ecology there is a lot of pressure on management to dispose them off in an environmental friendly way of the lack of information of the materials demanded in the small markets. Top management is highly involved in the core activities of the organization that is why they least bother to the rejections.

3.6 Poor Measurement System

In most of the organizations there is no formal mechanism for measurement. Usually they combine all waste under one head. No doubt the selling is item wise and the income generated is booked in the accounting ledger the amount recovered against scrap or waste That is why, one can not exactly have details what they have sold in which category. That hampers the good decision making with respect to the disposal initiatives.

3.7 Forecasting and Planning Constraints

MNCs and System Based Organizations have the estimated values for the reverse logistics that is usually based on previous year's estimates, future sales projections and the defect reduction initiatives. In spite of all these efforts, there are some anomalies like variation in the temperature of cold storage in the system that results in huge quantities. Industrial waste contractor is supposed to lift the material and suppose to line up the resources accordingly.

3.8 Inadequate Information System

Information System support always adds the value in reverses logistics for the identification of the rejections in every stage along with determining the impact on the bottom line. Most of the companies usually have inadequate information system and their conventional information systems do not contain the information about reverse logistics.

3.9 Environmental and Legal Issues

Due to green logistics, industrial ecology and life cycle assessment [3] there is a lot of pressure on management to dispose off reverse materials in an environmental friendly way. The Heavy pollution charge, bad impact on brand image and the closure of the businesses compel the management to take appropriate measures to handle the materials. Land filling of waste is not the effective way to dispose off the material rather it imposes the unacceptable environmental risks [15].

3.10 Absence of Performance Indicators

Absence of the performance indicators with respect to the reverse logistics is as well the source of impediment. Waste percentage and value recovered is the generic indicators usually used in the industry. There is a strong need to establish some indicators to effectively monitor the reverse logistics.

4. METHODOLOGY

4.1 Reverse Logistics and Scope

In the manufacturing units and corporate world, returns are very much imbedded in the system. There are some returns from customers [4] due to not meeting the customer's specifications and some time there are returns during the manufacturing process because of unsatisfactory parameters or characteristics of the product within the manufacturing units. It happens many times distributors take the materials back just to ensure the effective implementation of the product recall procedure. Whatever the reason is product returns [4] exist in the system and one of the important processes of reverse logistics [18]. Different types of the returns materials are defined as under:

I. Manufacturing Returns
   a) Scrap
   b) Defectives
   c) Rework
   d) By products
   e) Planned waste
   f) Production left-over

II. Distribution Returns
   a. Product recall
   b. Promotional material returns
   c. Customer returns (Retailer, whole saler, Distributor)
   d. Stock adjustments
   e. B2B commercial returns

f. Packaging

III. Customer Returns

a. Excess quantities

b. Rejected materials

c. Service returns (spare parts, repair)

d. B2C Commercial returns

e. Reimbursement

f. Warranty claims

g. End of lease returns

h. End of life returns

The above-mentioned returns are the generic returns identified from the literature; actual types of waste explored through the study of 50 companies are mentioned in Table 1, Table 2, Table 3 and Table 4. Types of the waste are taken from the list of contractual items. List of the companies explored is mentioned in Table 6. Sampling is convenience and snowball and random in nature. It is good to know that one of the important trends in supply chain management is recognition of the reverse logistics operations. These reverse logistics operations include many recycling activities like re-use, repair, re-furbish, re-assemble, re-manufacture and reduce the environmental impact performing variety of activities like dumping, biogas generation, and composting [16].

TYPES OF REVERSE LOGISTICS

Followings are the types of waste:

Sr. No.	Nutritional Wastes	Sr. No.	Biodegradable Wastes
1.	Chips	1.	Rotten Potato
2.	Starch	2.	Potato Soil
3.	Potato Peel and Hash	3.	WWTP Sludge
4.	Undersize Potato	4.	Kitchen Waste
5.	Biscuits Crumb	5.	Melted ice cream
6.	Broken Sweets	6.	Rotten milk
7.	Rotten Milk	7.	Rotten cheese
8.	WWTP FAT	8.	Wood
9.	Vegetable Used Oil		
10.	Meal Waste		

Table 1. Nutritional and biodegradable waste.

Sr. No.	Metallic Wastes	Sr. No.	Plastic Wastes
1.	Iron Scrap	1.	Polyethylene
2.	Iron Drums	2.	Polypropylene
3.	Stainless Steel Scrap	3.	Poly Film
4.	Mix Metal Scrap	4.	High Density
5.	Aluminum	5.	Laminates Wrapper
6.	Tin	6.	Empty Palm Oil Bags
7.	Copper	7.	Film Waste
8.	Electric Cables	8.	PET Materials
9.	Brass	9.	Rubber/plastic items
10.	Machinery Scrap	10.	Plastic Drums
11.	Computer scrap hardisk/casing	11.	Plastic Cans
12.	Cast Iron	12.	Hard Rubber
13.	Silver can/bottles	13.	Printer Cartridge

Table 2. Metallic and plastic waste.

Sr. No.	Paper/ Ghatta Wastes	Sr. No.	Chemicals Wastes
1.	Ghattah /Carton	1.	FFA
2.	Ghattah Rolls	2.	POV
3.	Newspaper	3.	Nitric Acid
4.	Stationary Paper	4.	Used Mobile Oil
5.	Paper Strips	5.	Ink residuals
6.	Gum paper	6.	Solvents Waste
7.	Cigarette Paper	7.	HCL
8.	Wrapping Paper	8.	Sulpheric Acid
9.	Filter Paper	9.	Caustic Soda
10.	Toffee Paper	10.	Borax

Table 3 Paper/ghatta and chemical waste.

Sr. No	Non-Organic Wastes	Sr. No	Bags Wastes
1.	Glasswares	1.	Description
2.	Sanitary wares	2.	PP Bags
3	Lino Kinari	3	Leno Bags
4.	Cotton Lint	4.	Paper Bags
5.	Cotton Yarn	5.	Cement Bags
6.	Sizing materials	6.	Meal / Seasoning Bags

Table 4. Non-organic and bag waste.

Waste Contractors and Recyclers			
Sr. No.	Organized Recyclers	Sr. No.	Non-Organized Recyclers
1.	Waste Busters	1.	Malik Plastics
2.	Green Earth Recycling	2.	Saddaqat Recyclers
3.	Tradeasia	3.	Many more
4.	Punjab Nylo Block Recycling Plant		
5.	Lahore Compost Pvt Ltd		
6.	Lahore Solid Waste Management Company		

Table 5 Waste contractors & recyclers. Industries being explored for reverse logistics.

System-based Companies	5. Maxim International
1. Tetra Pak	6. Service Industries
2. Nestle	7. Green Earth Recycling
3. Pepsi Cola International Pvt Ltd	8. Darson Industries
	9. Spelling Packaging
4. Unilever Pakistan	10. Kohinoor Textile Mills
5. Coco Cola	11. Farhaj Footware Pvt Ltd
6. Packages Ltd	12. Pioneer Board Mills
7. Pakistan Tobacco	13. Shan Food Pvt Ltd
8. Descon Engineering	14. Servaid Pharmacy
9. CCL Pharam	15. Matrix Sourcing
10. Treat Corporations	16. Infnity Engineering Pvt. Ltd.
11. Packaging Solutions	17. Bunny Food Industries
12. Irfan Textile	
13. Bullah Shah Paper Mill	**Owner-based Companies**
14. Century Paper Mill	1. Express Pac Pvt Ltd
15. Walls Ice Cream Pvt	2. Vandana Pvt Ltd
16. Khanewal Tea Factory	3. Organon Live Stock Feeding
17. Key Emms Pvt Ltd. Faisabalad	
18. Bata Pvt Ltd.	4. Tradeasia
19. METRO	5. Waste Buster
20. Coca Cola	6. Metal Forming Pvt Ltd
	7. Chaudry Rice Mills
Manager-based Companies	8. Shahraj Textile Mills
1. Asian Food Industries	9. Wali Oil Mills
2. Ravi Motorcycles	10. Plasplastics
3. Mian Tyre and Rubber industries	11. Mehrab Packaging
	12. Gul Ahmed
4. DIC Ink Factory	13. Gourmet Bottling Plant

4.2 Operational Framework of Reverse Logistics

The reverse logistics has a strategic importance in the feld of supply chain.[11] This operational framework of reverse logistics is designed and developed on the basis of exploratory study of Industries mentioned in Table 6. Operational framework is the generic fow of reverse logistics in Pakistani Industries.

End consumer and retailer follow the stream of Local Waste Contractor (LWC) for packaging materials like empty can, empty wood boxes, and plastic materials. In case of product rejections, end consumer return material to retailer (RR) then retailer send this material back to wholesaler (WS) then distributor (DIS) and then company (CO). Wholesaler and distributor may have a link with Local Waste Collector (LWC) and Industrial Waste Contactor (IWC) depending upon his need but retailer has a single link with the local waste contactor for his reverse materials. Company always engage the Industrial Waste Contractors (IWC) as a supply chain partner for reverse logistics to ensure the effective and effcient disposal of material adding maximum value to company. Industrial Waste Contractor work with multiple recyclers (RC) and disposing off their material with best monetary recover. Recyclers after due segregation, cleaning and processing sell recycled materials to small manufacturers (SM). Few quantities go to

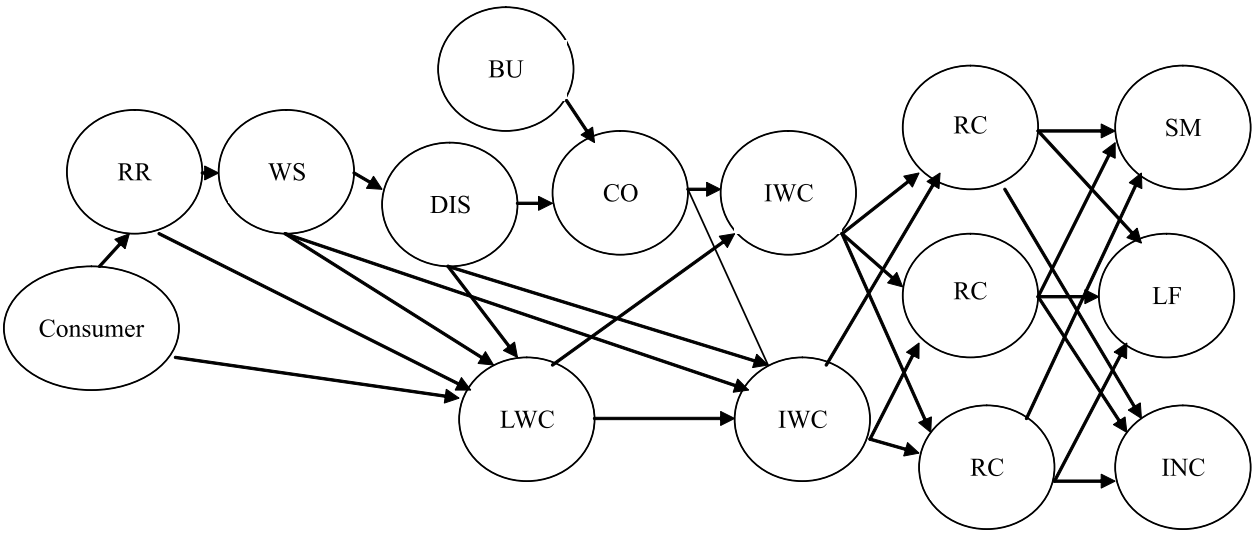

Fig. 1. Operational framework of reverse logistics.

dumping stations for land filling (LF) purpose and some which cannot be land filled met the fate of incinerations (INC). This framework is designed on the basis of study of fifty companies indicated in Table 6. The waste items generated from these companies helps to develop the generic flow of waste items coming from end consumer and industries and going back to industries, recyclers, dumping stations and incinerators depending upon the material type, recycling process and nature of the items shown in Table 1-4. Recyclers highlighted in Table 5 are keen for capacity building and keep on adding the new recycling techniques to dispose off waste items as per the requirements of Environmental Protection Agency (EPA).

4.3 Limitations of the Operational Framework

The operational framework of reverse logistics does not encompass the waste of following areas:

1. Hospital waste
2. Municipal waste
3. Radioactive waste
4. Agricultural-based waste
5. Cold storage waste
6. Pharmaceutical waste
7. Hazmat materials for high tech equipment
8. Meat waste

4.4 Assumptions

The assumptions of the framework are as under:

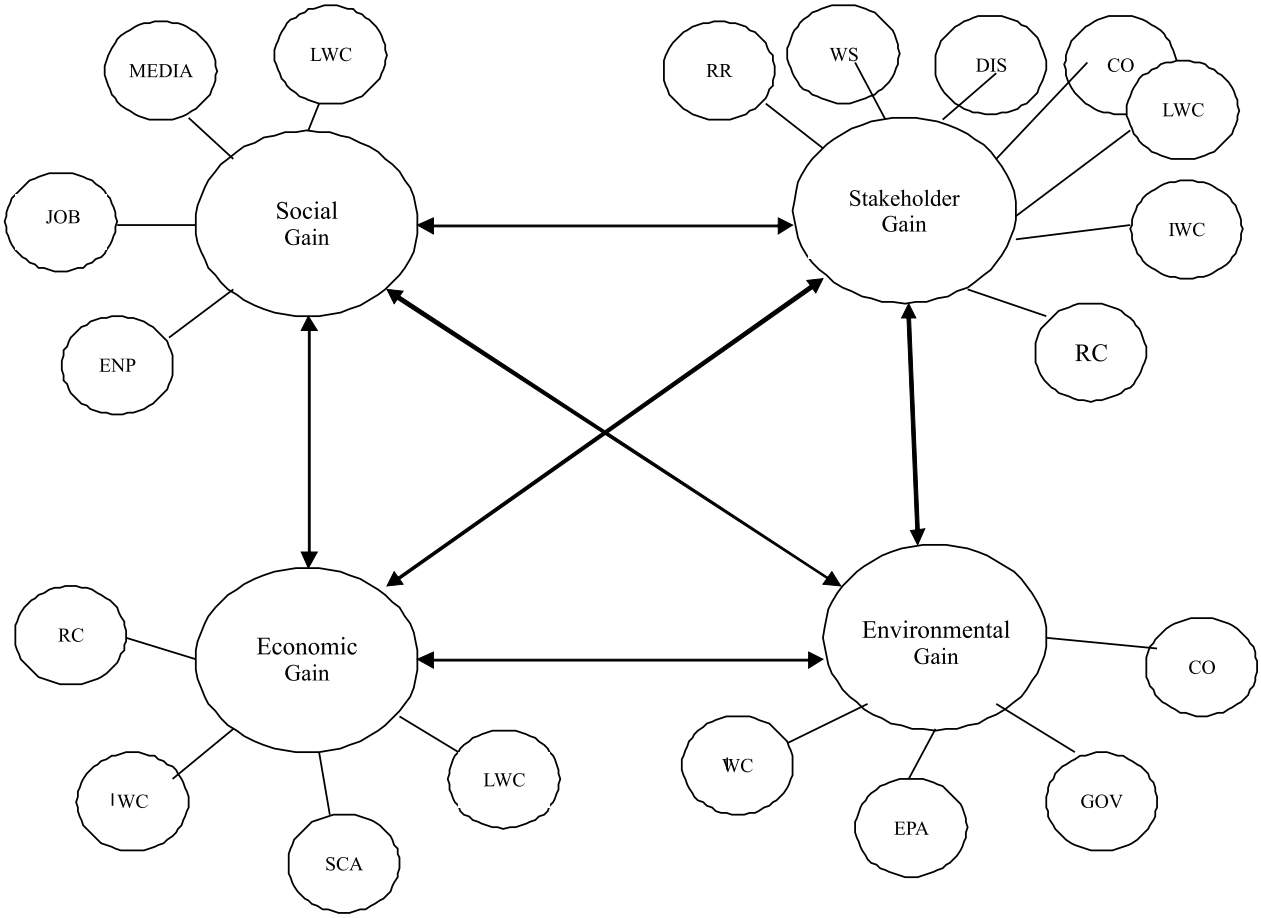

Fig. 2 2S-2E self sustained gain model.

Abbreviations in Fig. 2:

RR = Retailer
WS = Wholesaler
EPA = Environmental Protection Agency
DIS = Distributor
ENP = Entrepreneurial Spirit
MEDIA = Media Fear
IWC = Industrial Waste Collector
RC = Recycler
LWC = Local Waste Collector
Job = Job Opportunity/Employability
GOV = Government
SCA = Supply Chain Actors

1. End consumer does not hold / store the packaging materials and empty products.
2. End consumer sells packaging materials and scrap to Local Waste Collector and in case of defective product procured returned to retailer. Medical waste is not the part of the operational model.
3. Retailer sells outer packaging to local waste collector and rejections sends back to wholesaler, wholesaler to distributor and then company. Wholesaler and distributor may engage the Local waste collector or Industrial Waste Contractor depending upon his need and volumes of the waste materials and may return materials to company.
4. Wholesaler and distributor may engage the Local waste collector or Industrial Waste Contractor depending upon his need and volumes of the waste materials and may return materials to company.
5. Medical waste is not the part of the operational model.
6. Retailer sells outer packaging to local waste collector and rejections sends back to wholesaler, wholesaler to distributor and then company.
7. Wholesaler and distributor may engage the Local waste collector or Industrial Waste Contractor depending upon his need and volumes of the waste materials and may return materials to company.
8. Company always engages the Industrial Waste Contractor for the disposal of reverse logistics.
9. Operational Framework of the reverse logistics gives the driving power to SSEE Self Sustained Model for its operation. Media fear, environmental concerns, competition and monetary returns drive this model that ultimately ends up with four gains, i.e., stakeholders' gain, social gain, economic gain and environmental gain, which are elaborated as under:

A. Stakeholders' Gain

a. Stakeholders have win-win situation
b. Everyone earns benefts
c. Everyone love economic activity as it enhances the quality of life
d. Stakeholder's gain provides business opportunity
e. Stakeholder's gain drives value chain among all stakeholders and associated partners like transporter

B. Social Gain

a. Employability
b. Moral compensation
c. Job Opportunities
d. Encouraging entrepreneurial spirit
e. Media Fear
f. Entrepreneurial Spirit
g. Social Corporate Responsibility

C. Economic Gain

a. Creating impact at company productivity
b. Wealth creation
c. Cost Reduction
d. Monetary value addition
e. Enhancing profit margins

D. Environmental Gain

a. Environmental care
b. Environmental awareness
c. Green Image and Clean environment
d. Saving environment for future generations
e. Avoiding Pollution Charge
f. Enforcement of Environmental Laws

Social gain loop has single variable linkages and multi-variable linkages. Social gain has a multivariable linkage with stakeholder gain building the brand image of the stakeholders.

Table 6 Industries being explored for reverse logistics.

Sr. No.	Multi-Variable Linkages	Impact
1.	Social Gain – Stakeholder Gain	Protect Brand Image, Enhance Goodwill
2.	Social Gain – Environmental Gain	Green and Save Environment
3.	Social Gain – Economic Gain	Encourage Recycling
4.	Stakeholder Gain – Environmental Gain	Contribute towards Social Corporate Responsibility
5.	Stakeholder Gain – Economic Gain	Win-win opportunity
6.	Economic Gain – Environmental Gain	Creating wealth through proper recycling

Table 7 Multi variable linkages and its impact.

Sr. No.	Single-Variable Linkages	Impact
1.	Social Gain--- Media	Media fear encourage towards corporate citizenship
2.	Social Gain--- Jobs	It enhances more job and employability
3.	Social Gain--- Local Waste Collectors	Local waste collector gets good return and hire more persons as employees.
4.	Social Gain--- Entrepreneurial Spirit	Wave of entrepreneurial spirit spreads and encourage people to build the career as a entrepreneur
5.	Environmental Gain--EPA	Strengthen the role of Environmental Protection Agency
6.	Environmental Gain--Govt	Establish the good governance from governmental side
7.	Environmental Gain--IWC	Encourage the Industrial Waste Contactors to manage the things in an environmental friendly way
8.	Environmental Gain--CO	Building the company image in general public and in society as a environmental friendly company
9.	Economic Gain --- LWC	Local Waste Collector (LWC) gets its own share
10.	Economic Gain --- RC	Recycler (RC) gets good return
11.	Economic Gain --- IWC	Industrial Waste Contractor (IWC) gets more contracts and good returns
12.	Economic Gain --- SCA	Supply Chain Actors (SCA) get nominal chunk due to various reasons.
13.	Stakeholder Gain --- RR	Retailer (RR) gets money back guaranty
14.	Stakeholder Gain --- WS	Wholesaler (WS) gets as per its contract
15.	Stakeholder Gain --- DIS	Distributor (DIS) sends back material to company and money back
16.	Stakeholder Gain --- CO	Company either hold the supplier or employees for continuous improvement and earns good reputation
17.	Stakeholder Gain --- RC	Recycler being the part of reverse logistics love to have such gain
18.	Stakeholder Gain --- IWC	Industrial Waste Contractor gets its own share
19.	Stakeholder Gain --- LWC	Local Waste Collector sells product to industrial waste contactor and generate revenue

5. REVERSE LOGISTICS ACTIVITIES

1.	Reuse	(Value added)
2.	Recycle	(Value added)
3.	Repair machinery / equipment	(Value added)
4.	Refurbish	(Value added)
5.	Reclaim materials	(Value added)
6.	Salvage	(Value added)
7.	Remanufacture	(Value added)
8.	Recondition	(Value added)
9.	Resell products	(Value added)
10.	Return to supplier	(Value added)
11.	Recover Chemicals	(Value added)
12.	Re-assemble	(Value added)
13.	Compositing	(Value added)
14.	Landfll	(Non-value added)
15.	Incineration	(Non-value added)

6. BEST PRACTICES FOR REVERSE LOGISTICS

6.1 Identify the Right 3PL

Identi f cation of the right Industrial Waste Contractor (IWC) is one of the biggest challenges. Lucrative returns attract many 3PL service providers to quote the bid at high rate to grab the contract and sometime few companies award the contract on the basis of price tag without properly evaluating the infrastructure, capacity and capability of 3PL service providers. Company must evaluate the Industrial Waste Contractor on the basis of full box view comprehending all the areas. Environmental disposal and optimal gain on the basis of win-win approach should be the winning principle. Zero sum game while engaging the contractor may deface the company image and mar the corporate citizenship.

6.2 Explore the Sustainable Solution

Appoint a Sustainability Manager who must work for sustainable solutions [8] for the reverse logistics and keep on working with Industrial Waste Contractors [13] for more value addition initiatives. Manager and Industrial Waste Contractor must

be awarded at the end of year for the cost cutting initiatives and exploring the value added recycling activities.

6.3 Make the System Auditable

Enhance the visibility in the system. Encourage documentation. Keep on conducting the second party audits to the Industrial Waste Contractor and customers of Industrial Waste Contractors. Second party audits not only help to identify the opportunities for improvement but as well ensure the effective and environmental friendly disposal of reverse logistics.

7. CONCLUSIONS

This paper presents a framework that is operational in the feld of reverse logistics and highlights the 2S-2E Self Sustained Gain Model that is basically the main driver behind this operational fow. Open media, environmental awareness, brand image, and social corporate responsibility are key variables that provide the conducive climate for its success. List of recycling categories and the value and non-value added activities are a way to bring effective disposal of environmental pollutants [16]. Best practices are the real strength of company to enhance visibility, check appropriateness and search long term sustainable, economically viable, environmental friendly, labour intensive solutions. This paper encourages strategic managers to focus this forgotten dimension and pushing the tactical managers for exploring sustainable competitive advantages. Mathematical modeling and the System Dynamics modeling are open areas for research in future.

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Research Article

Studies on a Rare and Exceptionally Occurring Brown Alga, *Padinopsis adriatica* Ercegović

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Abstract: A brown alga of extremely rare occurrence *Padinopsis adriatica* Ercegović, was collected from the Arabian Sea coast at Karachi, Pakistan during March 2008 and investigated for its morphology, anatomy and reproductive structures in details. This is the first report of its occurrence in the Indian Ocean. The present specimens were slightly larger in length and breadth than the type specimens. Thallus was observed to grow by a margin of apical cells and there is lack of an inrolled margin which distinguishes it from the genus *Padina*. Anatomical features and reproductive structures observed in this study are new information for this species.

Keywords: Marine algae, *Padinopsis,* Phaeophycota, morphology, anatomy, reproduction

1. INTRODUCTION

During a collection survey of marine benthic algae at the coast of Karachi, (Pakistan) from March 2006 and June 2010, a very rare alga *Padinopsis adriatica* Ercegović (family Dictyotaceae, order Dictyotales, class Dictyophyceae, phylum Phaeophycota; *fide* [1]) was found as drift material. It was not collected during previous surveys of Pakistan coast [2-6]. It was also not reported earlier from the Indian Ocean [7]. This provided a good opportunity to investigate its morphology, anatomy and reproductive structures in detail.

2. MATERIALS AND METHODS

The specimens were collected during March 2008 from Buleji, a coastal area near Karachi, Pakistan. Material was brought to the laboratory, washed thoroughly and preserved in 4 % formalin-seawater solution for further investigation. Some material was preserved in the form of herbarium sheets and kept in the herbarium, Department of Botany, Federal Urdu University, Karachi (FUU-SWH). Cross sections (C.S.) of the material were obtained by free hand cutting with the help of shaving blades, which were then stained with iodine, mounted in glycerine and sealed with the help of nail polish. Prepared slides were examined under Nikon PFX microscope, photographs were taken with F 601 camera and developed in a photolab with *hp* scanner. The photographic plates were prepared in Adop photoshop 7.0 with the help of a computer.

3. RESULTS AND DISCUSSION

The general observation and microscopic investigation of the collected specimens indicated the following characters.

***Padinopsis adriatica* Ercegović 1955: 44**

References: Ercegović 1955:44, Giaccone 1978: 92, Antolić *et al*. 2010: 12, Guiry & Guiry 2011:2427, Abbas & Shameel 2012: 110 [8-12].

3.1. Morphological Characters

Thallus olive green in colour, 4.7 cm in height, divided into two portions *i.e.* upper broad fan like portion and lower narrow stipe; upper portion 3 cm

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long and lower stipe 1.7 cm long; thallus 1.2 cm broad at the apex, 1 cm broad in the middle; stipe 5 mm broad at upper part, 4 mm broad in the middle and 1 – 2 mm broad at the base; surface smooth, margin in upper part uneven or dentate, stipe more or less smooth; oogonia present in the form of rows at upper part and scattered in the lower part; oogonia and hair-lines alternate to each other or in concentric rows (Fig. 1); at the apex, marginal incisions present (Fig. 2).

3.2. Anatomical Features

In surface view: peripheral cells light brown, small, cubical, thin-walled, arranged in vertical rows, not dorsiventrally differentiated, 5.0 – 22.5 µm in length and 5 – 20 µm in breadth; sporangial lines present alternate to the hair lines (Fig. 3).

In the apical portion: thallus consists of 4 layers *i.e.* upper and lower peripheral layers and 2 cortical layers, thallus 82.5 µm broad; peripheral cells cubical or quadratic, some cells slightly elongated, lower peripheral cells same in size and shape, but in upper epidermis some cells more or less rounded, some slightly elongated and some cubical, thick walled, cell-wall thickness 7.5 µm, with dense phaeoplasts, 25 – 35 µm in length and 25 – 35 µm in breadth; cortical cells small, cubical or quadratic, thin walled, poor in contents, 17.5 – 25.0 µm in length and 17.5 – 22.5 µm in breadth (Fig. 4).

In the middle part: two peripheral layers enclosing 2 cortical layers, thallus 100 µm broad; peripheral layers consist of cubical or quadratic, thick walled cells, cell-wall thickness 7.5 µm, with dense phaeoplasts, 17.0 – 27.5 µm in length and 22.5 – 37.5 µm in breadth; 2 layered cortex consists of cubical or quadratic, thin walled cells, poor in contents, 15 – 30 µm in length and 15.0 – 22.5 µm in breadth (Fig. 5).

In the basal portion: thallus consists of 6 layers *i.e.* upper and lower peripheral and 4 cortical layers, thallus 162.5 µm broad; peripheral cells slightly elongated, cubical, some cells at upper side become slightly rounded and appear to be dome shaped, thick walled, cell-wall thickness 7.5 µm, with dense phaeoplasts, 15 – 30 µm in length and 22.5 – 37.5 µm in breadth; cortical layers consist of cubical, thick walled cells, cell-wall thickness 7.3 µm, poor in contents, 15 – 30 µm in length and 15 – 25 µm in breadth (Fig. 6).

3.3. Reproductive Structures

Sporangia present on upper surface of thallus in the form of concentric sori, reddish brown, globular or slightly elongated, induciate, found in groups (Fig. 7), 50 – 100 µm in length and 45 – 100 µm in breadth (Fig. 8).

Growth: By margin of apical cells.

Habitat: Collected as drift material at Goth Haji Ali, Buleji (*Leg.* Alia Abbas, 14-3-2008).

Type locality: Island of Jabuka, central Adriatic Sea.

Local distribution: Karachi: Buleji.

Distribution in the Indian Ocean: Pakistan only.

3.4. Remarks

It is the type species of the genus *Padinopsis* Ercegović. This genus is being reported for the first time not only from the coast of Pakistan but from the Indian Ocean as a whole. It was not previously found in the Indian Ocean at all [7]. This species was initially collected from 50-70 m depth of central Adriatic Sea [8]. It seems to be so rare that probably its other citations from Adriatic Sea [9, 10, 13] only refer to the old publication of Ercegović, where they did not have additionally sampled new material. Some considered this species as *taxon inquirendum* [14], but others accepted it. This is not its first collection from Karachi, but during a survey in 1980s a much larger specimen of this species was collected by Shameel from Buleji coast of Karachi, and its identification was kindly confirmed by late Prof. Nizamuddin who was working at that time at Libyan coast of Mediterranean Sea. He took the sample to Libya to compare it with the type specimen but unfortunately lost it somewhere. The present record from sub-littoral depth of northern Arabian Sea appears to be the second sample at all after its type specimen.

The present specimens are slightly larger in length and breadth, originally they were found up to 3 cm tall and 3.5 cm broad [8]. Thallus was observed to grow by a margin of apical cells, there is lack of inrolled margin, which distinguishes it

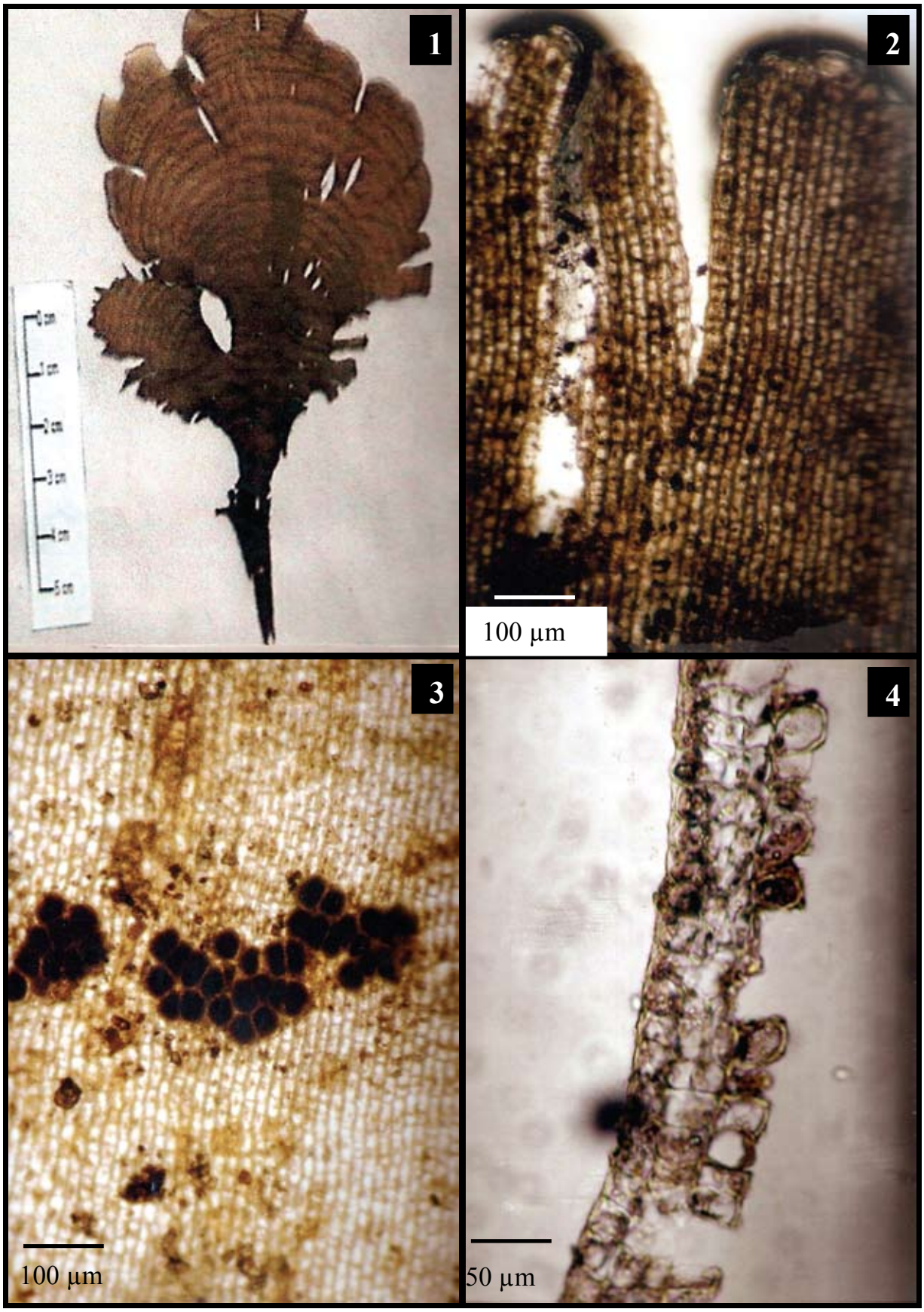

Fig. 1-4. *Padinopsis adriatica*: **1.** Habit of the thallus; **2.** Surface view of thallus showing marginal incision; **3.** Surface view with line of sporangia; **4.** C.S. of apical portion of thallus.

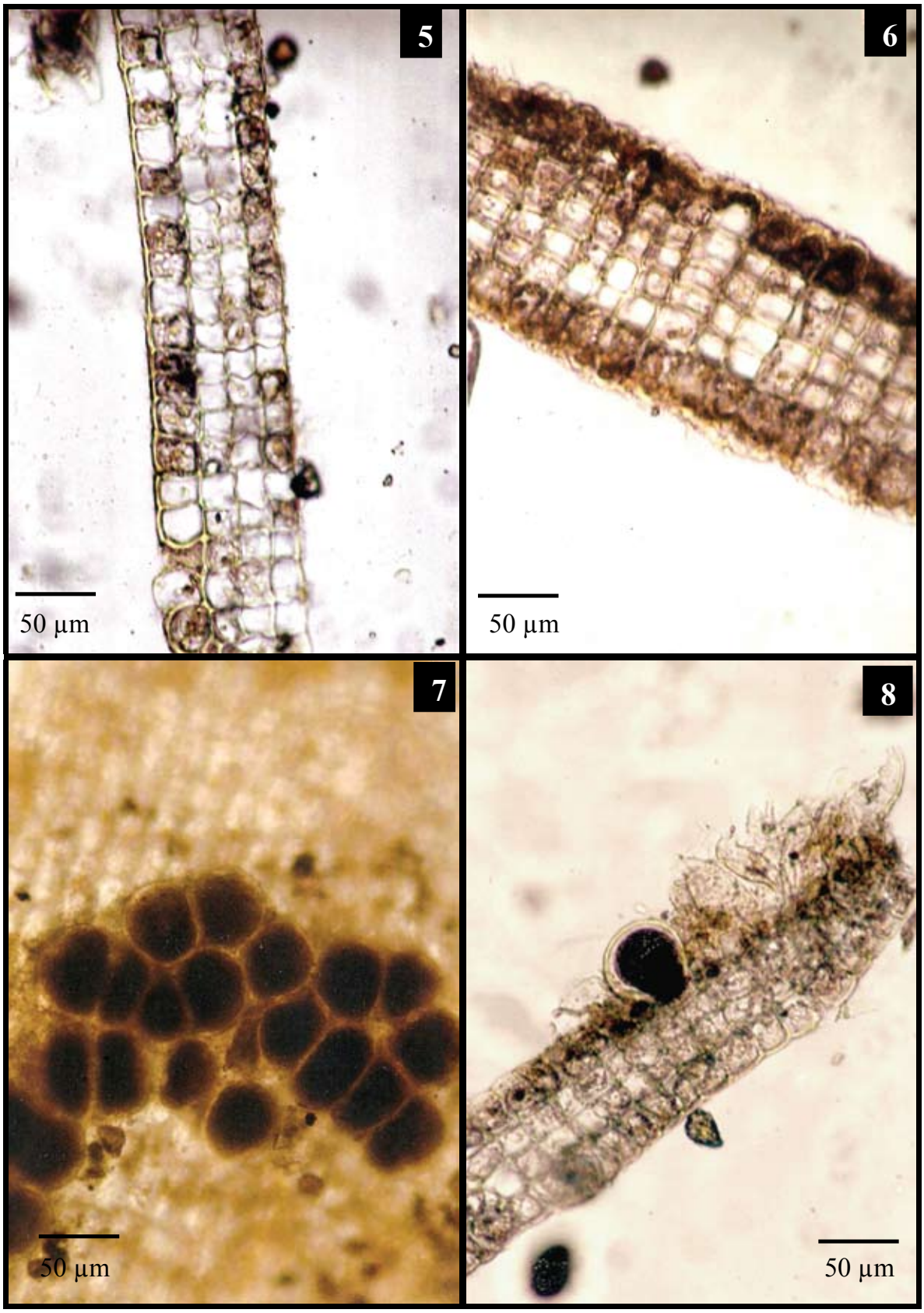

Fig. 5-8. *Padinopsis adriatica*: **5.** C.S. of middle part of thallus; **6.** C.S. of basal portion; **7.** Sporangial sori; **8.** C.S. of thallus showing a sporangium.

from the genus *Padina.* Phaeoplasts are discoid, which appear quadrangular in cross section. In this type specimen, blade margin was observed to be monostromatic, soon becoming distromatic by a longitudinal division of subapical cells [8]. Thallus of the present specimen multistromatic, where cell layers increased in the basal portion. Anatomical features and reproductive structures observed in the present study are new information for this species. The present description of the reproductive organs is the frst one, as no reproductive structures were recorded previously [8-10].

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