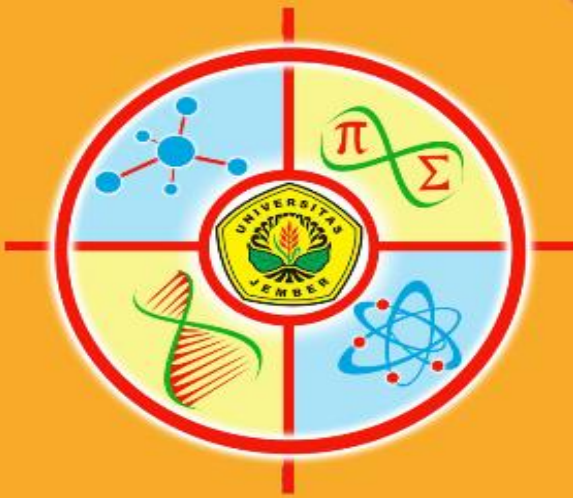


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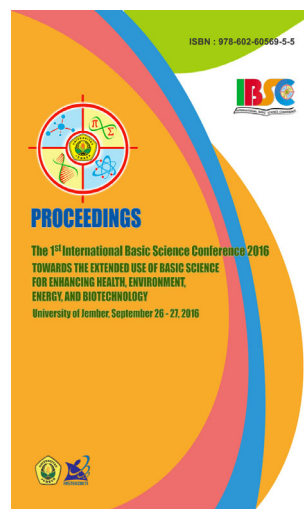




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## **GENERAL**

---

## **Community Strategy for Managing Tropical Forest Resources in The Area of Cagar Alam Pulau Sempu (Nature Reserve of Sempu Island)**

Lely Mardiyanti, Rifalatul Isnaini, Sueb Sueb

2-6



PDF

---

## **BIOREDUCTION ADSORBENT (BIOSORBENT): RECOVERY TECHNOLOGY OF HEAVY METAL POLLUTION (CADMIUM/CD) IN POLLUTED LAPINDO WATER SOURCES USING BACTERIA AND DURIAN LEATHER**

Sueb Sueb, Eka Imbia Agus Diartika, Khasanah Sripalupi, Achib Irmawati

7-9



PDF

---

## **COMPARATIVE STUDY OF THE MANAGEMENT OF VANAME SHRIMP (LITOPENAEUS VANNAMEI) BASED ON DEMOGRAPHIC FACTORS AT MOLANG BEACH TULUNGAGUNG**

Firda Ama Zulfia, Ika Airin Nur Rohmadhani, Nova Yesika Gultom, Sueb Sueb

10-12



PDF

---

## **ANALYSIS OF THE INFLUENCE OF PUBLIC PARTICIPATION IN THE MANAGEMENT OF RESOURCES SUSTAINABLE WATER MALANG DISTRICT**

Ahmad Kamal Sudrajat, Dewi Nur Arasy, Daning Nindya Fitri Arianti, Sueb Sueb

13-15



PDF

---

## **CONSERVATION COCCINELLA SP. AS PREDATOR OF GREEN PEACH APHID MYZUS PERSICAE SULZER ON POTATO INTERCROPPING**

Lamria Sidauruk

16-18



PDF

---

## **THE EFFECT OF MYCORRHIZAL INOCULANT AND COMPOST OF VOLCANIC ASH ON GROWTH AND YIELD OF CHILLI (CAPSICUM ANNUM L.)**

Ernitha Panjaitan, Nur Syntha Napitupulu, Ezra Matondang

19-22



PDF

## **THE POTENTIAL OF ARTHROPODE DIVERSITY FOR ECOTOURISM DEVELOPMENT IN WONOREJO MANGROVE ECOSYSTEM, SURABAYA**

Nova Maulidina Ashuri, Abdul Azis, Noor Nailis Sa'adah

23-26



PDF

---

## **THE EFFECTS OF WATER FRACTION OF BITTER MELON (MOMORDICA CHARANTIA) LEAF EXTRACT IN MAMMARY GLAND DEVELOPMENT OF BALB/C MICE (MUS MUSCULUS) WITH HISTOLOGICAL AND MOLECULAR BIOLOGICAL ANALYSIS OF PROTEIN APPROACHES**

Nur Hayati, Afifah Nur Aini, Nafisatuzzamrudah Nafisatuzzamrudah, Umie Lestari

27-29



PDF

---

## **COMPETITIVENESS AND POTENTIAL OF SHEEP LIVESTOCK AS SOURCE INCREASING INCOME AND PROVIDER OF MEAT ANIMAL IN NORTH SUMATRA**

Sarim Sembiring

30-31



PDF

---

## **MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERS OF CASSAVA (MANIHOT ESCULENTA CRANTZ) WHICH WET TOLERANT**

Rahmawati Rahmawati, Tri Agus Siswoyo, Didik Puji Restanto, Sri Hartatik, Sigit Soeparjono, Sholeh Avivi

32-35



PDF

---

## **THE EFFECT OF SOY TEMPEH FLOUR EXTRACT ON VAGINA HISTOLOGICAL STRUCTURE OF SWISS WEBSTER OVARIECTOMIZED MICE (MUS MUSCULUS)**

Mahriani Mahriani, Eva Tyas Utami, Dita Ayu Faradila

36-38



PDF

---

## **THE TOXICITY OF SEEDS EXTRACT OF ANNONA SQUAMOSA L., LEAVES EXTRACT OF TERMINALIA CATAPPA L. AND LEAVES EXTRACT OF ACACIA NILOTICA L. ON THE MORTALITY OF AEDES AEGYPTI L. LARVAE**

Dwi Wahyuni, Sandy Pradipta, Muhammad Ramadhan

39-41



PDF

## **ELEPHANTOPUS SCABER AND SAUROPUS ANDROGYNUS REGULATE MACROPHAGES AND B LYMPHOCYTE CELLS DURING SALMONELLA TYPHI INFECTION**

Muhammad Sasmito Djati, Dinia Rizqi Dwijayanti, Lulut Dwi Nurmamulyosari, Yayu Fuadah, Muhammad Basyarudin, Nur Jannah

42-44



---

## **The Effort To Increase Production of Super Red Dragon Fruit (*Hylocereus costaricensis*) By Artificial Pollination**

Neni Andayani, Lailatun Naria Latifah, Theresia Maria Astuti

45-46



---

## **EVALUATION OF ZONATION OF THE MANGROVE CONSERVATION AREAS IN PAMURBAYA**

Viv Djanat Prasita, Agus Subianto, Asbar Asbar

47-49



---

## **INPUT OF NUTRIENT (NITROGEN AND PHOSPHORUS) FROM THE CATCHMENT AREA INTO RAWAPENING LAKE OF CENTRAL JAVA**

Agatha Sih Piranti, Diana RUS Rahayu, Gentur Waluyo

50-51



---

## **RELATIONSHIP BETWEEN WATER QUALITY AND ABUNDANCE OF CYANOPHYTA IN PENJALIN RESERVOIR**

Badrun Mahera Agung, Agatha Sih Piranti, Carmudi Carmudi

52-56



---

## **HEMATOLOGICAL CHARACTERISTIC OF THE FEMALE ASIAN VINE SNAKE (*AHAETULLA PRASINA* BOIE, 1827)**

I Gusti A. Ayu Ratna Puspita Sari, Endah Sri Palupi

57-59



## HIGHLY SPESIFIC BACILLUS CEREUS-PHAGES ISOLATED FROM HOSPITAL WASTEWATER IN BANYUMAS REGENCY

Anwar Rovik, Saefuddin 'Aziz, Hendro Pramono

60-64



PDF

---

## BIOSYNTHESIS SILVER NANOPARTICLE USING FRESH WATER ALGAE

Dahlia Dahlia, Sherry Aristyani, Robiatul Hadawiyah

65-66



PDF

---

## EFFECT OF SAPONIN-PODS EXTRACT ACACIA (ACACIA MANGIUM) TO HEMATOCRIT, HEMOGLOBIN AT TILAPIA (OREOCHROMIS NILOTICUS)

Is Yuniar, Win Darmanto, Agoes Soegianto

67-69



PDF

---

## EFFECT OF DISSOLVED NUTRIENT CONCENTRATION (NITRATE AND ORTHOPHOSPHATE) ON ABUNDANCE OF CHLOROPHYTA IN PENJALIN RESERVOIR BREBES REGENCY

Novi Ariyanti, Carmudi Carmudi, Christiani Christiani

70-73



PDF

---

## THE ANATOMY OF CAROTENE BIOSYNTHESIS IN BETA VULGARIS L., VAR. RUBRA USING SCAN ELECTRON MICROSCOPE

Dahlia Dahlia

74-76



PDF

---

## OPTIMIZATION OF YOGURT FERMENTED MILK PRODUCTS WITH THE ADDITION OF NATURAL STABILIZER BASED ON LOCAL POTENTIAL OF TARO STARCH (COLOCASIA ESCULENTA)

Aju Tjatur Nugroho Krisnaningsih, Dyah Lestari Yulianti, Imam Thohari, Puguh Surjowardojo

77-79



PDF

---

## PTERIDOPHYTES OF ALAS PURWO NATIONAL PARK AND THEIR MEDICINAL POTENCY

Fuad Bahrul Ulum, Dwi Setyati

80-82



PDF

---

### **GENETIC VARIATION OF Aedes Aegypti (DIPTERA : CULICIDAE) BASED ON DNA POLYMORPHISM**

Rike Oktarianti, Sri Mumpuni

83-84



PDF

---

### **THE EFFECT OF SOY TEMPEH FLOUR EXTRACT TO UTERINE HISTOLOGY OF OVARIECTOMIZED MICE**

Eva Tyas Utami, Mahriani Mahriani, Nidaul Hikmah

85-87



PDF

---

### **MATING BEHAVIOUR OF CROCIDOLOMIA PAVONANA F.**

Purwatiningsih Purwatiningsih, Mirza Devara

88-90



PDF

---

### **THE DEVELOPMENT OF SUSTAINABLE RESERVE FOOD GARDEN PROGRAM'S VIDEO IN MALANG CITY**

Benny Satria Wahyudi, Mimien H. I Al-Muhdhar, Sueb Sueb, Susilowati Susilowati, Endang Budiasih

92-96



PDF

---

### **EFFECT OF MEDIUM COMPOSITIONS ON THE GROWTH OF RICE (ORYZA SATIVA L. CV. CIHERANG) CALLUS**

Ruliana Umar, Yossi Wibisono, Netty Ermawati

97-100



PDF

---

### **BLOOD FIGURE OF RAMBON CATTLE FED FORMULATED CONCENTRATE CONTAINING SOYBEAN CAKE, POLLARD AND CORN OIL COMBINE WITH UREA XYLANASE MOLASSES CANDY**

Emy Koestanti, Romziah S., Tri Bhawono D.

101-102

 PDF

---

### **STRATEGIES FOR DEVELOPMENT OF BEEF CATTLE FARMING BASED ON INNOVATION TECHNOLOGY AND FEEDING PROGRAM TO MEET SELF SUFFICIENCY IN MEAT**

Romziah S., Hario P. S., Tri Bhawono D.

103-105

 PDF

---

### **MODIFICATION OF BEAN SPROUT AND UREA MEDIA TO SPIRULINA PLATENSIS CULTURE**

Nadya Adharani, Selly Candra Citra, Nova Bagus Hidayat, Agung Hermawan Susanto, Angga Saputra

107-110

 PDF

---

### **COLLAGEN FROM SEA CUCUMBER (STICHOPUS VARIEGATUS) AS AN ALTERNATIVE SOURCE OF HALAL COLLAGEN**

M. H. Khirzin, Sukarno Sukarno, N. D. Yuliana, Laily Yunita Susanti, E. Chasanah, Y. N. Fawziya

111-113

 PDF

---

### **DEVELOPMENT OF NEW PRODUCT "COCOA SPIRULINA AS FUNCTIONAL FOOD"**

Asmak Afriliana, Achmad Subagio, Aminah Abdullah

114-119

 PDF

---

### **THE PROTEIN AND WATER CONTENT OF TEN VARIATIONS OF THE FEED CASSAPRO OF YEAST TAPE**

Indrawaty Sitepu

120-122

 PDF

---

### **EFFECT OF POMELO (CITRUS GRANDIS) ETHANOLIC EXTRACT ON ATHEROSCLEROTIC PLAQUE FORMATION**

Mudzakkir Taufiqurrahman, Kiky Martha Ariesaka, Hilda Khairinnisa, Wahyu Dian Puspita, Azka Darajat, Al Munawir

124-126





---

## CLINICAL MANIFESTATION OF ORAL TUBERCULOSIS

Atik Kurniawati, Ni Made Mertaniasih, Mangestuti Agil

127-131



---

## IDENTIFICATION OF DERMATOPHYTES BY MULTIPLEX-POLYMERASE CHAIN REACTION, POLYMERASE CHAIN REACTION-RESTRICTION FRAGMENT LENGTH POLYMORPHISM ITS1-ITS4 PRIMERS AND MVAI, AND POLYMERASE CHAIN REACTION (GACA)<sub>4</sub> PRIMER

Rizalinda Sjahril, Firdaus Hamid, Aan Yulianingsih, Novita Prastiwi, Awaluddin Awaluddin, Siska Nuryanti, Faridha Ilyas, Burhanuddin Bahar

132-135



---

## [RETRACTED] IMPACT PSYCHOLOGICAL AND PSYCHO-PHYSICAL WORK DISTRESS ON TOOTH MOBILITY IN RAT MODEL (ARTICLE RETRACTED FROM IBSC PROCEEDING)

Zahreni Hamzah, Suhartono Taat Putra, Elyana Asnar STP

136-139

---

## ROLE OF REACTIVE OXYGEN SPECIES ON DEVELOPMENTS OF OSTEOCLASTOGENESIS IN AGING

Dyah Indartin Setyowati, Zahreni Hamzah, Zahara Meilawaty

140-143



---

## DETERMINANT FACTOR THAT INFLUENCED ANXIETY LEVEL AND ENERGY INTAKE AMONG ELDERLY

Ninna Rohmawati

144-146



---

## P-CARE BPJS ACCEPTANCE MODEL IN PRIMARY HEALTH CENTERS

Hosizah Hosizah

147-150



## THE EFFORT OF TB CADRE IN THE IMPROVING OF THE SUCCESS OF TB THERAPY AND REDUCING SIDE EFFECTS OF ANTI TUBERCULOSIS DRUGS

Dewi Rokhmah, Khoiron Khoiron, Elly Nurus Shakinah, Ema Rahmawati

151-152



PDF

---

## RISK FACTOR OF GREEN TOBACCO SICKNESS (GTS) AT THE CHILDREN ON TOBACCO PLANTATION

Dewi Rokhmah, Khoiron Khoiron

153-156



PDF

---

## DIRECT SCATTERING PROBLEM FOR MICROWAVE TOMOGRAPHY

Agung Tjahjo Nugroho

158-161



PDF

---

## MICROSTRUCTURE AND MECHANICAL PROPERTIES OF DISSIMILAR JOINT OF COLD ROLLED STEEL SHEETS 1.8 SPCC-SD AND NUT WELD M6 BY SPOT WELDING

Ratna Kartikasari, Mustakim Mustakim, Joko Pitoyo, Feri Frandika

162-164



PDF

---

## FEATURE EXTRACTION OF HEART SIGNALS USING FAST FOURIER TRANSFORM

Hindarto Hindarto, Izza Anshory, Ade Efiyan

165-167



PDF

---

## ANALYSIS OF EL NIÑO EVENT IN 2015 AND THE IMPACT TO THE INCREASE OF HOTSPOTS IN SUMATERA AND KALIMANTAN REGION OF INDONESIA

Ardila Yananto, Saraswati Dewi

168-173



PDF

---

## SYNTHESIS OF ZINC OXIDE (ZNO) NANOPARTICLE BY MECHANO-CHEMICAL METHOD

Siswanto Siswanto, Anita Yuliati, Mayasari Hariyanto

174-176



---

### MODELLING DYNAMICS OF ZNO PARTICLES IN THE SPRAY PYROLYSIS REACTOR TUBE

Diky Anggoro, Melania Muntini, Iim Fatimah, Sudarsono Sudarsono

177-180



---

### THE INFLUENCE OF EXTREMELY LOW FREQUENCY (ELF) MAGNETIC FIELD EXPOSURE ON THE PROCESS OF MAKING CREAM CHEESE

Andika Kristinawati, Sudarti Sudarti

181-183



---

### Au Grade of Epithermal Gold Ore at Paningkaban ASGM, Banyumas District, Central Java Province, Indonesia

Rika Ernawati, Arifudin Idrus, HTBM Petrus

184-187



---

### Renewable Energy Conversion with hybrid Solar Cell and Fuel Cell

Aris Ansori, Indra Herlamba Siregar, Subuh Isnur Haryuda

188-191



---

### Radar Absorbing Materials Double Layer From Laterite Iron Rocks And Activated Carbon Of Cassava Peel In X-Band Frequency Range

Linda Silvia, Bayu Aslama, Ega Novialent, M. Zainuri

192-194



---

### Instantaneous Analysis Attribute for Reservoir Characterization at Basin Nova-Scotia, Canada

Ruliyanti Ruliyanti, Puguh Hiskiawan, Artoto Arkundato

195-196



## Deployment Porosity Estimation of Sandstone Reservoir in The Field of Hidrocarbon Exploration Penobscot Canada

Himmah Khasanah, Puguh Hiskiawan, Supriyadi Supriyadi

197-198



PDF

---

## Seismic Resolution Enhacement with Spectral Decomposition Attribute at Exploration Field in Canada

Illavi Prasety Pebrian, Puguh Hiskiawan, Artoto Arkundato

199-203



PDF

---

## Simulation of I-V Characteristics of Si Diode at Difference Operating Temperature:Effect of Ionized Impurity Scattering

Siti Lailatul Arofah, Endhah Purwandari, Edy Supriyanto

204-206



PDF

---

## Simulation of self diffusion of iron (Fe) and Chromium (Cr) in Liquid lead by Molecular Dynamic

Ernik Dwi S, Artoto Arkundato, Supriyadi Supriyadi, Heru Baskoro, Elva Nurul F

207-208



PDF

---

## The Study of Electrical Conductance Spectroscopy of The Inner membrane of Salak

Wenny Maulina

209-210



PDF

---

## The Accuracy Comparison of Oscilloscope and Voltmeter Utilized in Getting Dielectric Constant Values

Bowo Eko Cahyono, Misto Misto, Rofiatun Rofiatun

211-213



PDF

---

## Window Filter (WinTer) To Capture Pollution of Lead (Pb) For Houses Near The Highway To Prevent Health Problems

Rifang Pri Asmara, Fitri Azizah, Siti Umi Afifah

214-215



PDF

---

### **Simulation of Solar Cell Diode I-V Characteristics Using Finite Element Methode: Influence of p- Layer Thickness**

Greta Andika Fatma, Endhah Purwandari, Edy Supriyanto

216-217



PDF

---

### **GIS-based optimization method for utilizing coal remaining resources and post-mining land use planning: A case study of PT Adaro coal mine in South Kalimantan**

Mohamad Anis, Arifudin Idrus, Hendra Amijaya, Subagyo Subagyo

219-225



PDF

---

### **Quantification Model of Qualitative Geological Data Variables for Exploration Risk Assessment in Prospect Cu-Au Porphyry Deposit Randu Kuning, Wonogiri, Central Java**

Nurkhamim Nurkhamim, Arifudin Idrus, Agung Harijoko, Irwan Endrayanto, Sapto Putranto

226-231



PDF

---

### **A Sensor-Based of Detection Tools To Mitigate People Live in Areas Prone to Landslide**

Satryo Budi Utomo, Januar Fery Irawan

232-236



PDF

---

### **Relocation of hypocenter using Jacobian's matrix and Jeffreys-Bullen's velocity model**

Faid Muhlis, Risca Listyaningrum, Indriati Retno Palupi

237-238



PDF

---

### **Analysis Of The Geothermal Potential Based Fault Zone In Burni Telong Bener Meriah, Aceh, Indonesia**

Gartika Setiya Nugraha, Marwan Marwan, Oky Ikhrallah, Susanti Alawiyah, Sutopo Sutopo

239-242



---

### Synthesis Of Zeolites From Lombok Pumice As Silica Source For Ion Exchanger

Mega Putri K., Regina G.L. D., Ade L.N. F., Haiyina H. A., Nura H. H., Darminto Darminto  
244-247



---

### Optimisation of Extractant and Extraction Time on Portable Extractor Potentiometric Method for Determining Phosphate in Soil

Anggia Rose Sukaton, Siswoyo Siswoyo, Bambang Piluharto  
248-252



---

### Analysis of protein profile of neem leaves juice (azadirachta indica L. Juss)

I Dewa Ayu Ratna Dewanti, I Dewa Ayu Susilawati, Pujiana Endah Lestari, Roedy Budirahardjo  
253-255



---

### Hydrophobic Aerogel-Based Film Coating On Glass By Using Microwave

Poerwadi Bambang, Diah Agustina E, Christia Meidiana  
256-258



---

### Preparation and Characterization of Cacao Waste As Cacao Vinegar And Charcoal

Mohammad Wijaya, Muhammad Wiharto  
259-261



---

### The Effect of Physico-Chemical Properties of Aquatic sediment to the Distribution of Geochemical Fractions of Heavy Metals in the Sediment

Barlah Rumhayati, Catur Retnaningdyah, Novi Anitra, Ahmad Dodi Setiadi  
262-265



---

### Increased Concentration of Bioethanol by Rectification Distillation Sieve Tray Type

Yuana Susmiati, Mochamad Nuruddin

266-269



PDF

---

### **Determination of Lead in Cosmetic Sampels Using Coated Wire Lead (II) Ion Selective Electrode Based On Phyropillite**

Qonitah Fardiyah, Barlah Rumhayati, Ika Rosemiyani

270-272



PDF

---

### **Pyrolysis Temperature Effect on Volume and Chemical Composition of Liquid Volatile Matter of Durian Shell**

Waode O.S. Ilmawati, M. Jahiding, Waode O.S. Musnina

273-275



PDF

---

### **High Performance Liquid Chromatography of Amino Acids Using Potentiometric Detector With A Tungsten Oxide Electrode**

Yeni Maulidah Muflihah, Zulfikar Zulfikar, Siswoyo Siswoyo, Asnawati Asnawati, Qurrota Ayun

276-278



PDF

---

### **Rainwater Treatment Using Treated Natural Zeolite and Activated Carbon Filter**

Lili Mulyatna, Yonik M. Yustiani, Astri Hasbiah, Widya Yopita

279-281



PDF

---

### **Filtration of Protein in Tempe Wastewater Using Cellulose Acetate Membrane**

Dwi Indarti, Badrut Tamam Ibnu Ali, Tri Mulyono

282-284



PDF

---

### **Image Encryption Technique Based on Pixel Exchange and XOR Operation**

Kiswara A. Santoso, Fatmawati Fatmawati, Herry Suprajitno

286-288



---

### **Fuzzy Anp Method And Internal Business Perspective For Performance Measurement In Determining Strategy SMEs**

Yeni Kustiyahningsih, Eza Rahmanita, Jaka Purnama

289-294



---

### **Application of Fuzzy TOPSIS Method in Scholarship Interview**

Abduh Riski, Ahmad Kamsyakawuni

295-298



---

### **The Effect of Inflation, Interest Rate, and Indonesia Composite Index (ICI) to the Performances of Mutual Fund Return and Unit Link with Panel Data Regression Modelling**

Siti S. Purwaningsih, Anny Suryani, Euis Sartika

299-302



---

### **Using Logistic Regression to Estimate the Influence of Adolescent Sexual Behavior Factors on Students of Senior High School 1 Sangatta, East Kutai-East Kalimantan**

Darnah Darnah, Memi Norhayati

303-306



---

### **Application Cluster Analysis on Time Series Modelling with Spatial Correlations for Rainfall Data in Jember Regency**

Ira Yudistira, Alfian Futuhul Hadi, Dian Anggraeni, Budi Lestari

307-310



---

### **A Zero Crossing-Virus Evolutionary Genetic Algorithm (VEGA) to Solve Nonlinear Equations**

M. Ziaul Arif, Zainul Anwar, Ahmad Kamsyakawuni

311-315





PDF

---

### **Analysis of Simultaneous Equation Model (SEM) on Non normally Response used the Method of Reduce Rank Vector Generalized Linear Models (RR-VGLM)**

Miftahul Ulum, Alfian Futuhul Hadi, Dian Anggraeni

316-318



PDF

---

### **The Rainbow (1,2)-Connection Number of Exponential Graph and It's Lower Bound**

Gembong A. W., Dafik Dafik, Ika Hesti Agustin, Slamin Slamin

319-320



PDF

---

### **Construction of Super H-Antimagicness of Graph by Uses a Partition Technique with Cancelation Number**

Rafiantika Megahnia Prihandini, Dafik Dafik, Ika Hesti Agustin

321-324



PDF

---

### **On The Total r-dynamic Coloring of Edge Comb Product graph $G \text{ D } H$**

Dwi Agustin Retno Wardani, Dafik Dafik, Antonius C. Prihandoko, Arika I. Kristiana

325-327



PDF

---

### **On The Metric Dimension with Non-isolated Resolving Number of Some Exponential Graph**

S. M. Yunika, Slamin Slamin, Dafik Dafik, Kusbudiono Kusbudiono

328-330



PDF

---

### **On Total r-Dynamic Coloring of Several Classes of Graphs and Their Related Operations**

Kusbudiono Kusbudiono, Desi Febriani Putri, Dafik Dafik, Arika Indah Kristiana

331-336



PDF

### **The Analysis of r-dynamic Vertex Colouring on Graph Operation Of Shackle**

Novita Sana Susanti, Dafik Dafik

337-339



PDF

---

### **On the Rainbow Vertex Connection Number of Edge Comb of Some Graph**

Agustina M., Dafik Dafik, Slamin Slamin, Kusbudiono Kusbudiono

340-342



PDF

---

### **On the edge r-dynamic chromatic number of some related graph operations**

Novian Nur Fatihah, Arika Indah Kriatiana, Ika Hesti Agustin, Dafik Dafik

343-346



PDF

---

### **Handling Outlier In The Two Ways Table By Using Robust Ammi And Robust Factor**

Kurnia Ahadiyah, Alfian Futuhul Hadi, Dian Anggraeni

347-350



PDF

---

### **An Epidemic Model of Varicella with Vaccination**

Qurrota A'yuni Ar Ruhimat, Imam Solekudin

351-355



PDF

---

### **The Correlation Between Perception And Behavior Of River Pollution By Communities Around Brantas Riverbank In Malang**

Kuni Mawaddah, Sueb Sueb

357-359



PDF

---

### **Isolation And Screening Of Specific Methicillin Resistant-Staphylococcus Aureus Bacteriophage From Hosiptal Waste At Banyumas**

Chairunisa Fadhilah, Saefuddin Aziz, Hendro Pramono

360-364



---

### **Co(III) as Mediator in Phenol Destruction Using Electrochemical Oxidant**

Herlina Herlina, Derlini Derlini, Muhammad Razali

365-369



---

### **Design of System Batch Injection Analysis (BIA) for Monitoring the Production of Alcohol (II)**

Tri Mulyono, Dwi Indarti, Rizqon Rizqon

370-374



---

### **Preliminary Study Gold Mineralization Hosted By Metamorphic Rocks In The Southeastern Arm Of Sulawesi, Indonesia**

Hasria Hasria, Arifudin Idrus, I Wayan Warmada

375-378



---

### **Effects of Packaging Types on Moisture Content, Microbe Total and Peroxide Value of Instant Ganyong (*Canna edulis* Kerr) Yellow Rice**

Lilis Sulandari

379-383



---

### **Resistivity Value as Characteristics Of Majapahit Kingdom Era Red Bricks**

Supriyadi Supriyadi, Nurul Priyantari, Rosaria Dwi Sukmadewi

384-385



---

### **Strategy to Increase Contract Farming Satisfaction on Red Chili Farmer with The Hortikultura Lestari Cooperation (Evidence : Dukuh Dempok Village Wuluhan District)**

Hesti Herminingsih

386-390



## On The Metric Dimension with Non-isolated Resolving Number of Some Exponential Graph

S.M. Yunika<sup>1,2</sup>, Slamir<sup>1,4</sup>, Dafik<sup>1,3</sup>, Kusbudiono<sup>1,2</sup>

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**Abstract**—Let  $w, w \in G = (V, E)$ . A distance in a simple, undirected and connected graph  $G$ , denoted by  $d(v, w)$ , is the length of the shortest path between  $v$  and  $w$  in  $G$ . For an ordered set  $W = \{w_1, w_2, w_3, \dots, w_k\}$  of vertices and a vertex  $v \in G$ , the ordered  $k$ -vector  $r(v|W) = (d(v, w_1), d(v, w_2), \dots, d(v, w_k))$  is representations of  $v$  with respect to  $W$ . The set  $W$  is called a resolving set for  $G$  if distinct vertices of  $G$  have distinct representations with respect to  $W$ . The metric dimension  $dim(G)$  of  $G$  is the minimum cardinality of resolving set for  $G$ . The resolving set  $W$  of graph  $G$  is called non-isolated resolving set if subgraph  $W$  is induced by non-isolated vertex. While the minimum cardinality of non-isolated resolving set in graph is called a non-isolated resolving number, denoted by  $nr(G)$ . In this paper we study a metric dimension with non-isolated resolving number of some exponential graph.

**Keywords**—Metric dimension, Non-isolated resolving number, Exponential graph.

### INTRODUCTION

A graph  $G$  is pair set  $(V, E)$  where  $V$  is not empty set of element called vertex, and  $E$  a set unordered pair of two vertices  $(v_1, v_2)$  where  $v_1, v_2 \in V$ , is called edges [1].  $V$  is called vertex set of  $G$ , and  $E$  is called edge set of  $G$  [2]. In the year of 1975, concept metric dimension introduced by Slater [3]. This concept show of resolving set known as locating set. Resolving set  $W$  defined as resolving of vertices in graph  $G$  so that for every vertices in  $G$  produce distance different of every vertex in  $W$ . Dimension metric is cardinality minimum of resolving set of graph  $G$  which denoted by  $dim(G)$  [4]. For sequence resolving  $W = w_1, w_2, w_3, \dots, w_n$  of vertex set in graph connected  $G$  and vertex  $v$  in  $G$ ,  $k$ -vector (k-tuple sequences)  $r = (v|W) = (d(v, w_1), d(v, w_2), \dots, d(v, w_k))$  [5]. Resolving set  $W$  of graph  $G$  is called non-isolated resolving set if subgraph  $W$  induced by isolated vertices. Cardinality minimum of non-isolated resolving number denoted by  $nr(G)$  [6]. Related research metric dimension is [7], [8], [9], [10]. In this research resulted metric dimension with non-isolated resolving number of some exponential graph.

### THE RESULTS

We are ready to show our main theorems. There are two theorems found in this study. These deals with exponential graph  $L_n^{P_m}$  and  $S_n^{P_m}$

**Theorem 1.** For  $n \geq 3$  and  $m \geq 4$ , the metric dimension and non-isolated resolving number of  $L_n^{P_m}$  are  $dim(L_n^{P_m}) = 2$  and  $nr(L_n^{P_m}) = m$ .

*Proof.* A exponential graph of  $L_n^{P_m}$  is a connected graph with vertex set  $V(L_n^{P_m}) =$

$$\begin{aligned} & \{x_i, y_i, z_{i,j}; 1 \leq i \leq n-1; 1 \leq j \leq m-2\} \cup \{x_{i,j}, y_{i,j}; 1 \leq i \leq n-1; 1 \leq j \leq m-2\}, \text{ and edge set } E(L_n^{P_m}) = \{x_i x_{i+1}, y_i y_{i+1}; 1 \leq i \leq n-1\} \cup \{x_{i,j} x_{i,j+1}, y_{i,j} y_{i,j+1}; 1 \leq i \leq n-1; 1 \leq j \leq m-3\} \cup \{z_{i,j} z_{i,j+1}; 1 \leq i \leq n; 1 \leq j \leq m-3\} \cup \{y_{i+1} y_{i,m-2}, x_{i+1} x_{i,m-2}; 1 \leq i \leq n-1\} \cup \{x_i z_{i,m-2}; 1 \leq i \leq n\}. \text{ Thus } |V(L_n^{P_m})| = 3nm - 2m - 4n + 4 \text{ and } |E(L_n^{P_m})| = 3nm - 2m - 3n + 2. \end{aligned}$$

For  $n \geq 3$  and  $m \geq 4$ , the minimum cardinality of resolving set is two, If it is one then there will be the same representation of every  $v \in V(L_n^{P_m})$  with respect to

representation of every  $v \in V(L_n^{P_m})$  with respect to  $W$  are as follow:

$$\begin{aligned} r(x_i|W) &= (mi - i, mi - m - i + 1); 1 \leq i \leq n \\ r(y_i|W) &= (mi - m - i + 1, mi - i); 1 \leq i \leq n \\ r(x_{i,j}|W) &= (m + 3i + j - 4, 3i + j - 3); 1 \leq i \leq n - 1; 1 \leq j \leq m - 2 \\ r(y_{i,j}|W) &= \{(3i + j - 3, m + 3i + j - 4); 1 \leq i \leq n - 1; 1 \leq j \leq m - 2\} \\ r(z_{i,j}|W) &= \{(3i + j - 3, 3i - j); 1 \leq i \leq n; 1 \leq j \leq m - 2\} \end{aligned}$$

It is easy to see that  $L_n^{P_m}$  has a different representation of every  $v \in V(L_n^{P_m})$  with respect to  $W$ . Therefore)  $dim(L_n^{P_m}) = 2$  concludes that  $dim(L_n^{P_m}) = 2$

The next it will be showed by  $nr(L_n^{P_m})$ . Based on observations Arumugam which state that  $nr(L_n^{P_m}) \geq dim(L_n^{P_m})$ . So That  $nr(L_n^{P_m}) \geq dim(L_n^{P_m}) = 2$ , however  $nr(L_n^{P_m}) \neq 2$  because it does not fulfill the character non-isolated resolving set that  $W = \{x_1, y_1\}$  it consists of dots which is not connected each other. For  $n \geq 3$  and  $m \geq 4$ , the minimum cardinality of non-isolated resolving set is  $m$ , otherwise there will be the same representation of every  $v \in V(L_n^{P_m})$  with respect to  $W'$ . Thus the lower bound of  $nr(L_n^{P_m}) \geq m$ . We will show that  $nr(L_n^{P_m}) \leq m$ , by choosing  $W' = \{x_1, y_1, z_{1,j}; 1 \leq j \leq m - 2\}$  as a non-isolated resolving set. Clearly that cardinality of  $|W'| = m$ . The representation of every  $v \in V(L_n^{P_m})$  with respect to  $W'$  are as follow:

$$\begin{aligned} r(x_i|W) &= \{(a_{i,k}); a_{i,k} = mi - i - k + 1; 1 \leq i \leq n; 1 \leq k \leq m\} \\ r(y_i|W) &= \{(b_{i,k}); b_{i,k} = mi - m - i - k; 1 \leq i \leq n; 1 \leq k \leq m\} \\ r(x_{i,j}|W) &= \{(a_{i,j,k}); a_{i,j,k} = mi - i + j - k + 1; 1 \leq i \leq n - 1; 1 \leq j \leq m - 2; 1 \leq k \leq m\} \\ r(y_{i,j}|W) &= \{(b_{i,j,k}); b_{i,j,k} = mi - i - m + j + k; 1 \leq i \leq n - 1; 1 \leq j \leq m - 2; 1 \leq k \leq m\} \\ r(z_{i,j}|W) &= \{(c_{i,j,k}); 1 \leq i \leq n; 1 \leq j \leq m - 2; 1 \leq k \leq m\} \end{aligned}$$

where

$$c_{i,j,k} = \begin{cases} j, & \text{for } i = 1; 1 \\ & \leq j \leq m - 2; \\ & k = 1 \\ k - j - 1, & \text{for } i = 1; 1 \\ & \leq j \leq m - 2; \\ & j + 1 \leq k \leq \\ & m \\ j - k + 1, & \text{for } i = 1; 2 \\ & \leq j \leq m - 2; \\ & 2 \leq k \leq j \\ im - m - i + k + j, & \text{for } 2 \leq i \leq n; \\ & 1 \leq j \leq m - \\ & 2; 1 \leq k \\ & \leq \\ & m - j \\ im + m - i - k - j, & \text{for } 2 \leq i \leq n; \\ & 1 \leq j \leq m - \\ & 2; m - j \leq k \\ & \leq m \end{cases}$$

It is easy to see that  $L_n^{P_m}$  has a different representation of every  $v \in V(L_n^{P_m})$  with respect to  $W'$ .

Therefore,  $\mathbf{nr}(L_n^{P_m}) = m$  for  $n \geq 3$  and  $m \geq 4$ .  $\square$

**Theorem 2.** For  $n \geq 3$  and  $m \geq 4$ , the metric dimension and non-isolated resolving number of  $S_n^{P_m}$  are  $\dim(S_n^{P_m}) = n - 1$  and  $\mathbf{nr}(S_n^{P_m}) = n$ .

*Proof.* A exponential graph of  $S_n^{P_m}$  is a connected graph with vertex set  $V(S_n^{P_m}) = \{A\} \cup \{x_i; 1 \leq i \leq n\} \cup \{x_{i,j}; 1 \leq i \leq n; 1 \leq j \leq m - 2\}$ , and edge set  $E(S_n^{P_m}) = \{Ax_{i,1}, x_i x_{i,m-2}; 1 \leq i \leq n\} \cup \{x_{i,j} x_{i,j+1}; 1 \leq i \leq n; 1 \leq j \leq m - 3\}$ . Thus  $|V(S_n^{P_m})| = n + nm - 2n + 1$  and  $|E(S_n^{P_m})| = nm - n$ .

For  $n \geq 3$  and  $m \geq 4$ , the minimum cardinality of resolving set is  $n - 1$ , otherwise there will be the same representation of every  $v \in V(S_n^{P_m})$  with respect to  $W$ . Thus the lower bound of  $\mathbf{dim}(S_n^{P_m}) \geq n - 1$ . We will show that  $\mathbf{dim}(S_n^{P_m}) \leq n - 1$ , by choosing  $W = \{x_{i,1}; 1 \leq i \leq n - 1\}$  as a resolving set. Clearly that cardinality of  $|W| = n - 1$ . The representation of every  $v \in V(S_n^{P_m})$  with respect to  $W$  are as follow:

$$\begin{aligned} r(A|W) &= \{(a_k); a_k = 1; 1 \leq k \leq n - 1\} \\ r(x_i|W) &= \{(a_{i,k}); 1 \leq i \leq n; 1 \leq k \leq n - 1\} \end{aligned}$$

where

$$a_{i,k} = \begin{cases} m - 2, & \text{for } i = k \\ m, & \text{for } i \text{ and } k \text{ other} \end{cases}$$

$$r(x_{i,j}|W) = \{(b_{i,j,k}); 1 \leq i \leq n; 1 \leq j \leq m - 2; 1 \leq k \leq n - 1\}$$

where

$$b_{i,j,k} = \begin{cases} j - 1, & \text{for } 1 \leq i \leq n - 1; \\ & 1 \leq j \leq m - 2; k = i \\ j + 1, & \text{for } 1 \leq i \leq n; \\ & 1 \leq j \leq m - 2; k \neq i \end{cases}$$

It can be seen that every vertex of graph  $S_n^{P_m}$  has a different representation to  $W$ , so the cardinality minimum resolving set of graph  $S_n^{P_m}$  which chosen is  $|W| = |\{x_{i,1}; 1 \leq i \leq n - 1\}| = n - 1$  or  $\dim(S_n^{P_m}) \leq n - 1$ . Therefore proved that  $\dim(S_n^{P_m}) = n - 1$  for  $n \geq 3$  and  $m \geq 4$ .  $\square$

The next it will be showed by  $\mathbf{nr}(S_n^{P_m})$ . Based on observations Arumugam which state that  $\mathbf{nr}(S_n^{P_m}) \geq \dim(S_n^{P_m})$ . So That  $\mathbf{nr}(S_n^{P_m}) \geq \dim(S_n^{P_m}) = n - 1$ , however  $\mathbf{nr}(S_n^{P_m}) \neq n - 1$ , because it does not the character non-isolated resolving set that  $W = \{x_{i,1}; 1 \leq$

$i \leq n - 1\}$  it consist of vertex which is not connected each other. For  $n \geq 3$  and  $m \geq 4$ , the minimum cardinality of non-isolated resolving set is  $n$ , otherwise there will be the same representation of every  $v \in V(S_n^{P_m})$  with respect to  $W'$ . Thus the lower bound of  $\mathbf{dim}(S_n^{P_m}) \geq n$ . We will show that  $\mathbf{nr}(S_n^{P_m}) \leq n$ , by choosing  $W' = \{A, x_{i,1}; 1 \leq i \leq n - 1\}$  as a non-isolated resolving set. Clearly that cardinality of  $|W'| = n$ . The representation of every  $v \in V(S_n^{P_m})$  with respect to  $W'$  are as follow:

$$r(A|W') = \{(a_j); a_j = 1; 1 \leq j \leq n - 1\}$$

where

$$a_k = \begin{cases} 0, & \text{for } k = 1 \\ 1, & \text{for } 2 \leq k \leq n - 1 \end{cases}$$

$$r(x_i|W') = \{(b_{i,k}); 1 \leq i \leq n; 1 \leq k \leq n - 1\}$$

where

$$b_{i,k} = \begin{cases} m - 2, & \text{for } 1 \leq i \leq n - 1; k = i + 1 \\ m - 1, & \text{for } i = k \\ m, & \text{for } i \text{ and } k \text{ other} \end{cases}$$

$$r(x_{i,j}|W') = \{(c_{i,j,k}); 1 \leq i \leq n; 1 \leq j \leq m - 2; 1 \leq k \leq n - 1\}$$

where

$$c_{i,j,k} = \begin{cases} j, & \text{for } 1 \leq i \leq n; 1 \leq j \leq m - 2; \\ & k = 1 \\ j - 1, & \text{for } 1 \leq i \leq n - 1; 1 \leq j \leq \\ & m - 2; k = i + 1 \\ j + 1, & \text{for } 1 \leq i \leq n; 1 \leq j \leq m - 2; \\ & k \neq 1 \text{ and } k \neq i + 1 \end{cases}$$

It is easy to see that  $S_n^{P_m}$  has a different representation of every  $v \in V(L_n^{P_m})$  with respect to  $W'$ . Therefore  $\mathbf{nr}(S_n^{P_m}) \leq n$ . It concludes that  $\mathbf{nr}(S_n^{P_m}) = n$  for  $n \geq 3$  and  $m \geq 4$ .  $\square$

## CONCLUDING REMARKS

We have shown the metric dimension number and metric dimension non-isolated resolving number of exponential graph, namely  $L_n^{P_m}$  and  $S_n^{P_m}$ . The results show that the metric dimension numbers and metric dimension non-isolated resolving numbers attain the best lower bound. However we have not found the sharpest lower bound for general graph, therefore we proposed the following open problem.

**Open Problem 1.** Let  $H$  be any graph and  $P_m$  be a resolving number of  $H$ . metric dimension non-isolated

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