RESEARCH PAPER | Biochemistry | Volume : 3 | Issue : 8 | Aug 2013 | ISSN - 2249-555X

Existance of Soil Flora in the Soils of Oil Palm Growing Areas of Andhra Pradesh

KEYWORDS: Oil Palm, soil microbes, soil mineral nutrition, Nitrification

G. Swarna latha	Dr. Amara Srinivasulu	G. Suneetha
Department of Biochemistry, Andhra University, Visakhapatnam, India.	Department of Biochemistry, V.S. Lakshmi College, Kakinada, India.	Department of Biochemistry, GITAM University, Visakhapatnam, India

ABSTRACT *A study was undertaken to assess the status of soil microbes in oil palm plantation and its contribution to organic matter and mineral nutrients. The soil microbes are present far and wide. Plants are unable to take nutrition without microbes in the soil. Microbes are alive, and must have nutrition to survive, which comes from organic matter. Microbes consume nutrients, microbes undergo metabolism of nitrogen, carbon, oxygen, hydrogen, phosphorus, potassium, and trace minerals for plants. The microbes convert nitrogen, phosphorus, potassium, and minerals in the soil to produce food and flowers into a form by which the plants can use. The results revealed that soils are acidic to slightly alkaline and reveals the existence of microorganisms within 15 mandals of Andhra Pradesh, India. The most widely distributed microorganisms are observed in mandals of Bhimadolu, Chepurigudem, Jangareddygudem and Chepurigudem that are added to the yield of the micro-organisms. The widely distributed micro-organisms are Lactobacillus acidophilus, Salmonella typhimurium, Enterococcus faecalis, Serratia marcescens, Alcaligenes faecalis, Micrococcus ureae, Pseudomonas aeruginosa, Proteus vulgaris, Proteus mirabilis, Alcaligenes denitrificans, Serratia marcescens, Staphylococcus aureus, Neisseria gonorrhoeae, and Acinetobacter calcoaecticus.*

Introduction: The oil palm (Elaeis guineensis Jacq.) is a major plantation crop used in commercial production of palm oil. It is highly demanding crop for nutrients and early growth production. Hence, nutrient mining and soil productivity decline are the major concern of soil quality. Soil is the largest pool of soil microbes to increase the production of plant and its role as a key control of soil fertility and agriculture production. Most microbes need organic carbon to live; they get food from eating wood chips, leaves, manures, and other organic materials added to the soil. The microbes digest organic matter; and create humus which increases soil structure and is good for root penetration and development. Microbes also get some carbon from the rhizosphere (the area immediately around plant roots). The roots give substances like sugars and amino acids that can be used by microbes. The microbes convert into some other forms that plants can use, as minerals, vitamins, nitrogen, and amino acids. Some microbes like bacteria and blue-green algae are able to "fix" nitrogen from the air and make it available to the plants. Microbes create some nutrients, and other nutrients are added through fertilizers manually. Microbes improve soil structure by the humus they create while digesting organic matter.

Nitrification is a vital part of the nitrogen cycle, bacteria manufacture carbohydrate without using the process of photosynthesis. They are transformed to nitrogen and are available for growing plants. Nitrogen fixation is carried by free-living nitrogen-fixing bacteria in the soil such as Azotobacter. Denitrification converts nitrogen from the atmosphere into organic compounds, by a process called denitrification, which returns an approximately equal amount of nitrogen to the atmosphere. They include, Achromobacter and Pseudomonas. Actinobacteria undergoes decomposition of organic matter and in humus formation. Soil organic matter undergoes decomposition complex organic molecules of dead material into simpler organic and inorganic molecules (Juma, 1998). Decomposition of dead material results in the formation of a more complex organic matter called humus (Juma, 1998), which affects the properties of soil. As it slowly decomposes, it colours the soil darker; increases soil aggregation and aggregate stability; increases the CEC (the ability to attract and retain nutrients); and contributes N, P and other nutrients. Soil organisms break the organic matter, and excess nutrients (N, P and S) are released into the soil. Nitrosomonas is chemoautotrophic bacteria, which oxidizes ammonia into nitrite during the metabolic process. They increase the availability of nitrogen to plants, limiting carbon dioxide fixation. Nitrobacter is a genus of mostly rod-shaped, gram-negative and chemoautotrophic bacteria that plays an important role in the nitrogen cycle by oxidizing nitrite into nitrate in soil. Nitrobacter use energy from the oxidation of nitrite ions, NO_2^-, into nitrate ions, NO_3^-. Rhizobium is a genus of Gram-negative soil bacteria that fix nitrogen. The bacteria convert atmospheric nitrogen to ammonia and provide organic nitrogenous compounds.

Azotobacter is motile, oval or spherical and aerobic, free-living soil microbes which play an important role in the nitrogen cycle. Clostridium is a genus of Gram-positive bacteria which are obligate anaerobes capable of producing endospores the individual cells are rod-shaped or spindle.

Materials and methods:
Primary Cultures from Soil Extracts are prepared from unknown bacterium from soil. Soil samples are collected in triplicates from different villages in various districts. Each sample is collected in triplicate from different villages of different Mandals. Soil samples are dissolved in distilled water and subjected to colonies in the medium. Suspend organisms from the soil into TSB (tryptic soy broth). Secondary Cultures are prepared from Primary Cultures. This method identifies different colonies from their primary culture plates. The unknown bacteria are distinguished by the colour, texture, shape, and frequency. Colony characteristics of each pure culture, colour, texture, edge, elevation, and appearance are recorded. In the next step unknown Bacterium is identified by using various staining techniques. Staining is done by gram staining method, developed by Hans Christian Gram, (1850-1938). Endospore stain is followed by common staining procedure, called Schaeffer-Fulton by Perty, 1852; Pasteur, 1869; Koch, 1876; and Cohn, 1872. Moreover, acid-fast stain is developed by Zielh-Neelsen stain. Capsule stain is done by India ink-negative stain, by Anthony's capsule stain was developed by E. E. Anthony in 1931and Maneval's. Growth on selective and differen-

Volume : 3 | Issue : 8 | Aug 2013 | ISSN - 2249-555X

tial media was done by selective and differential media, by Robert Koch in 1883. Isolation of microbes is followed by serial dilution developed by Robert Koch, 2005. The next step is followed by starch hydrolysis, degradation of proteins, degradation of lipids, utilization of citrate, indole production from tryptophan, urea hydrolysis, sugar fermentation, H_2S Production, catalase test, oxidase, reduction of nitrate, and triple Sugar-Iron agar test. Biochemical Characterization is done by Indole test, MR (methyl red) test, VP test (vogues proskuer test), and citrate utilization test. This test is used in general characterization of many – ve and few gram + ve bacteria.

Results and Discussions:

The main objective of this study is to assess the impact of biotic and abiotic factors of the soil on the palm oil yield. The soil samples collected at different depth (0-15, 15-30 & 30-45cm) depths from 15 mandals of different villages of West Godavari districts of Andhra Pradesh representing intensive oil palm growing areas of (Table 1). Soils are acidic to slightly alkaline in nature. Soil samples were analysed, for the suitability of oil palm plantation by the determination of pH, EC, and existence of micro-organisms. The pH of the soil is an important physicochemical property, which influences the growth of palm trees, as it plays an important role in the maintenance of availability of nutrients, microbial activity, and soil texture. The ideal pH required for the optimum growth of the plants is in between 4 to 7. pH of the soils was determined by Sorenson's probe and meter method. Table 1 shows the results of the 51 samples collected at different depths from 17 mandals. This data clearly indicates that the pH range is in between 4.10 to 8.8. This also indicates that the top layer soil pH is slightly higher (5.14 to 8.8) than the middle (4.17 to 8.3) and lower layers (4.10 to 7.93). Hence, it is concluded that these soils are suitable for the oil palm plantation with minor modifications. The results in Table 2 depicts that soil contains sufficient soluble salts adversely to affect crop growth & production. It is however necessary to know the amount of salt in the soil for necessary treatment. The amount of salt in a soil can be precisely determined only by complete chemical analysis. But a close estimate can be obtained relatively easily by measuring Electrical Conductivity of Soil. The more the salts higher is the electrical conductivity. The Electrical Conductivity of a soil solution is determined by Wheat stone bridge method. The EC data in Table 2 shows the results of the 51 samples collected at different depths from 17 mandals with lower values. The most widely distributed microorganisms (Table 4) in bimadolu, mandal are Lactobacillus acidophilus, Salmonella typhimurium, Enterococcus faecalis, Serratia marcescens, and Alcaligenes faecalis. In the present study tadepalligudem mandal are distributed with the following microorganisms Alcaligenes faecalis, Micrococcus ureae, Salmonella typhimurium, Pseudomonas aeruginosa, Proteus vulgaris, Proteus mirabilis, Alcaligenes faecalis, and Proteus vulgarisi. In Buttayagudem the microorganisms distributed are Alcaligenes faecalis, Alcaligenes denitrificans, Serratia marcescens, Salmonella typhimurium, Alcaligenes faecalis and Staphylococcus aureus. Thus, Chepurigudem exists with the following microorganisms are Neisseria gonorrhoeae, Alcaligenes denitrificans, Acinetobacter calcoaecticus, Salmonella typhimurium, and Lactobacillus acidophilus. These microbes in the soil enhance the yield in oil palm plantation crops.

This paper provides an over view of the major challenges confronting the measurements of soil pH, EC, and microbes based on microbial turnover nutrients of soil. The purpose of the paper is to facilitate discussion on the existence of soil microbe to enhance the fertility status of soil in various oil palm growing areas and to relate to its productive potential which would be of prime importance for developing appropriate management practices for increased production.

Table – 1

MANDAL	VILLAGE	PH 1: 25 (w/v)		
		0-15 (cm)	15-30 (cm)	30-45(cm)
T. Narasapuram	Borammupalem	6.69	6.15	6.46
	Tedlam	5.8	6.29	6.33
	Bandivarigudem	6.9	7.02	6.87
Narasapur	Gondi	5.34	4.58	5.08
Buttaigudem	Kommugudem	6.03	5.78	5.37
	Buttaigudem	5.42	4.58	4.17
Pedavegi	Vegiwada	7.47	7.08	7.86
	Vijayarai	7.24	7.76	7.24
	Peddakadimi	8.18	8.3	7.88
	Garlamadugu	8.18	8.03	7.93
Nallajarla	Chepurigudem	5.14	4.18	4.63
	Ananthapalli	6.87	6.70	6.33
	Ayyavaram	6.77	7.0	6.84
	Gannavaram	7.0	7.3	7.06
	Gudepalli	5.63	5.85	5.73
	Ananthapalli	5.74	5.55	5.30
	Nallajarla	6.74	6.53	6.40
	Bapulapadu	7.77	7.86	7.87
Denduluru	Gangannagudem	7.41	7.29	6.98
	Galayagudem	7.36	7.38	7.33
Lingapalem	Kottapalli	7.48	7.35	7.31
Eluru	Chodimella	7.05	6.82	6.76
	Gudivakalanka	6.65	6.42	6.56
Bhimadolu	Polasannapalli	6.55	7.47	7.52
	Amberpet	6.65	6.73	6.74
Tadepalligudem	Pedatadepalligudem	6.17	6.16	5.94
	Madhavram	7.06	7.03	6.73
	Kadiyadda	7.49	7.52	7.35
	Kommugudem	7.49	7.16	7.21
	Bangurugudem	7.10	6.72	5.89
Nidadavolu	Kommamidi	7.16	7.56	7.63
	Tadimalla	7.71	7.68	7.69
Devarapalli	Yernagudem	7.24	7.30	7.25
	Gandhinagar	7.1	6.8	6.67
	Kalavalapalli	7.59	7.47	7.67
	Laxmipuram	5.26	4.17	4.10
Jangareddygudem	Jangareddy	5.30	5.02	4.98
	Mysannagudem	4.66	4.38	4.22
	Vallampatla	6.42	6.08	5.96

Volume : 3 | Issue : 8 | Aug 2013 | ISSN - 2249-555X

	Radhapuram	5.79	5.90	5.45
Pedagantiyadi	Dentakarra	8.38	8.05	7.72
Peddapappur	Chagallu	7.2	6.78	6.75
	Dharmapuram	7.4	7.59	7.55
Dwaraka tirumala	M.Nagulapalli	7.42	7.34	7.28
	G.kothapalli	7.95	7.60	7.15
	Narayanapuram	7.60	7.09	6.28
	Gunnam palli	7.82	7.93	7.78
	Laxminagar	7.03	7.42	7.54
	Rajupalem	7.40	7.36	7.40
	Pavulavarigudem	6.85	6.70	6.89
Kamarlakota	Polasigdem	6.89	7.28	7.12

Table – 2

MANDAL	VILLAGE	Electrical conductivity µS/m		
		0-15 (cm)	15-45 (cm)	45-60 (cm)
T. Narasapuram	Borammupalem	25.3us	33.6	53.8
	Tedlam	17.8	34.1	37.1
	Bandivarigudem	0.089	805us	0.090ms
Narasapur	Gondi	54.4	27	20
Buttaigudem	Kommugudem	83.1	61.6	0.127
	Buttaigudem	41.8us	38.2	76.5
Pedavegi	Vegiwada	0.087ms	0.096	0.091
	Vijayarai	0.103	62.8us	0.097ms
	Peddakadimi	0.130ms	0.205ms	0.134
	Garlamadugu	0.216	0.09	0.120
Nallajarla	Chepurigudem	52	77	75.2
	Ananthapalli	44.1	57.6	60.8
	Ayyavaram	69.8	48.2	49.7
	Gannavaram	0.11ms	77.5us	0.169ms
	Gudepalli	18.7us	15.8	16.2
	Ananthapalli	20.9	15.4	13.5
	Nallajarla	0.133ms	61.4us	67.9
	Bapulapadu	0.164ms	0.167	0.124ms
Denduluru	Gangannagudem	0.237ms	0.241	0.191
	Galayagudem	0.277	0.236	0.234
Lingapalem	Kottapalli	0.293	0.209	0.184
Eluru	Chodimella	0.323	0.352	0.35
	Gudivakalanka	0.28	0.257	0.239
Bhimadolu	Polasannapalli	0.104	66.0us	84
	Amberpet	63.2	37.8	43.4
Tadepalligudem	Pedatadepalligudem	82.1us	84.9	84.5
	Madhavram	0.147ms	0.141ms	0.175ms
	Kadiyadda	55.7	0.122ms	0.093
	Kommugudem	81.6us	49.6	59.1
	Bangurugudem	56.8	88	0.109ms
Nidadavolu	Kommamidi	77.7us	0.091ms	0.108
	Tadimalla	44.3us	49.6	50
Devarapalli	Yernagudem	54.3	43.9	29.7
	Gandhinagar	38.3	40.7	32.5
	Kalavalapalli	54.9	47.4	0.091ms
	Laxmipuram	43.8us	38.4	32.1
Jangareddygudem	Jangareddy	0.132ms	0.128	0.114
	Mysannagudem	0.234	0.202	0.159
	Vallampatla	57.0us	27.7	20.3
	Radhapuram	25.6	0.474ms	0.362
Pedagantiyadi	Dentakarra	0.195	0.181	0.120
Peddapappur	Chagallu	49.9us	30.3	29.1
	Dharmapuram	0.091ms	81.6us	0.096ms
Dwaraka tirumala	M.Nagulapalli	0.091	0.147	0.138
	G.Kothapalli	0.11	0.10	0.09
	Jajulakunta	0.098	0.20	0.218
	Gunnam palli	0.057	0.051	0.078
	Laxminagar	0.071	0.041	0.037
	Rajupalem	0.036	0.035	0.058
	Pavulavarigudem	0.045	0.044	0.045
Kamarlakota	Polasigdem	0.031	0.305	0.039

TABLE-3: Morphological Characteristics of the microbes

MANDAL	SHAPE	PIGMENT	MARGIN	ELEVATION	SURFACE	DENSITY	GRAM STAINING
Vegiwada	Mostly round, few are irregular, filamentous, rhizoid, oval, and filiform.	Mostly white and few are creamish to pink and orange.	Mostly smooth, few with lobate, few ciliate and few wavy.	Mostly flat, few umbonate, and few hilly.	Mostly shiny, and few powdery	Mostly opaque, very few are translucent.	Mostly positive bacilli, very few are –ve coccobacilli
Mundur	Mostly round, very few are rhizoid to irregular.	Few cream, few light orange,	Mostly smooth, few are wavy	Mostly flat and very few are hilly.	Mostly shiny, very few are dull and powdery	Mostly opaque, very few are transparent.	Mostly +ve cocci in groups, very few are –ve bacilli.
Koppulavarigudem	Mostly round	Mostly cream.	Mostly smooth, few are wavy	Mostly flat, few umbonate, and few hilly to convex.	Mostly shiny, very few are dull.	Mostly opaque, very few are transparent.	+ve cocci in chains and +ve cocci

Volume : 3 | Issue : 8 | Aug 2013 | ISSN - 2249-555X

Pedavegi	Mostly irregular, few with wrinkled.	Mostly cream, few with light golden.	Mostly irregular, few lobate, wavy, and smooth	Mostly hilly, very few are convex and flat.	Mostly shiny, and few powdery, and dull.	All are opaque.	-ve bacilli
Bimadolu	Mostly round	Mostly light cream.	Mostly smooth, few are wooly.	Mostly raised.	Mostly shiny, few are dull.	Mostly opaque.	-ve bacilli
Buttayagudem	Mostly round with scalloped margin.	Cream to whitish.	Mostly smooth to wavy.	Mostly flat and raised.	Mostly dull and few are shiny	Mostly opaque few translucent.	-ve bacilli
Chepurigudem	Mostly round.	Mostly light cream.	Mostly smooth.	Mostly flat and few convex.	All are shiny.	Mostly opaque few transparent.	-ve bacilli -ve cocco bacilli
Denduluru	Mostly round and few are irregular.	Mostly cream.	Mostly smooth.	Mostly flat and few convex.	Mostly dull.	Both transparent and opaque.	Mostly+ ve cocci, few – ve bacilli.
Jangareddy gudem.	Mostly irregular and spreading.	White.	Mostly smooth and few are wavy.	Convex and raised	Mostly shiny.	Mostly opaque	-ve cocco bacilli and –ve cocco bacilli.
Nallajarla	Mostly round.	Mostly white few cream.	Mostly smooth and few are hair loc and branching..	Convex, flat, and raised	All are shiny.	Mostly opaque and few transparent.	-ve bacilli and –ve cocco bacilli.
T. Narasapuram	Irregular and spreading	Mostly white few cream.	Mostly smooth and wavy.	Convex, flat, and raised	All are shiny and few are dull.	Mostly transparent and few opaque.	-ve cocci bacilli
Chepurigudem	Mostly round and very few are Irregular.	Mostly cream few white.	Mostly smooth.	Mostly flat and few convex.	All are shiny.	Mostly opaque, few are transparent.	-ve bacilli
Varapukota	Mostly round.	Yellow to white.	Mostly irregular and smooth.	Mostly flat, and convex.	All are shiny.	Mostly opaque.	- bacilli ve

Table- 4: Identification of bacteria by biochemical characteristics

Mandal	Microorganism identified							
Vegiwada	Bacillus pumilus	Acinetobacter calcoaceaticus	Bacillus pantothenticus	Staphylococcus capitis	Bacillus anthracis			
Mundur	Alcaligens denitrificans	Streptococcus mutans	Enterococcus casseliflavus	Staphylococcus caseolyticus	Staphylococcus auricularis	Bacillus badius	Bacillus pantothenticus	Staphylococcus capitis
Mundur	Bacillus alvei	Achromobacter xylosoxidans	Staphylococcus capitis	Pseudomonas stutzeri	Staphylococcus simulans	Pseudomonas diminute		
Koppulavarigudem	Bacillus stearothermophilus (Group II)	Streptococcus bovis biotype I	Bacillus lentus	Staphylococcus caseolyticus	Staphylococcus capitis			
Pedavegi	Achromobacter xylosoxidans	Pseudomonas diminuta	Pseudomonas putrefaciens	Salmonella pullorum	Pseudomonas cepacia	Klebsiella oxytoca		
Bimadolu	Lactobacillus acidophilus	Salmonella typhimurium	Enterococcus faecalis	Serratia marcescens	Alcaligenes faecalis			
Buttayagudem	Alcaligenes faecalis	Alcaligenes denitrificans	Serratia marcescens	Salmonella typhimurium	Alcaligenes faecalis	Staphylococcus aureus		
Chepurigudem.	Neisseria gonorrhoeae	Alcaligenes denitrificans	Acinetobacter calcoaecticus	Salmonella typhimurium	Lactobacillus acidophilus			
Denduluru	Enterococcus casseliflovus	Staphylococcus epidermis	Micrococcus luteus	Staphylococcus aureus				
Janga reddy gudem.	Alcaligenes denitrificans	Enterococcus faecalis						
Nallajarla	Kingella kingae	Acinetobacter lwoffi	Neisseria haemolysans	Acinetobacter calcoaecticus				
T.narasapuram	Kingella kingae	Pseudomonas pseudoalcaligenes	Moraxella lacunata					
Tadepalligudem	Alcaligenes faecalis	Micrococcus ureae	Salmonella typhimurium	Pseudomonas aeruginosa	Proteus vulgaris	Proteus mirabilis	Alcaligenes faecalis	Proteus vulgaris
Chepurigudem	Pseudomonas pseudoalcaligenes	Shewanella putrefaciens	Enterococcus durans					
Varapukota	Shigella flexneri	Neisseria gonorrhoeae						

Volume : 3 | Issue : 8 | Aug 2013 | ISSN - 2249-555X

REFERENCE

Adams GC, Kropp BR. (1996). "Athelia arachnoidea, the sexual state of Rhizoctonia carotae, a pathogen of carrot in cold storage". Mycologia88 (3): 459–472. | | Baillie A., Hodgkiss W., Norris J. R. (1962). "Flagellation of Azotobacter spp. as Demonstrated by Electron Microscopy". Journal of Applied Microbiology25 (1): 116–119. | | Benson, H. J. 1990. Data applications to systematics: Use of Bergey's manual and computer assistance. Pages 173–177, in Microbial applications. Fifth edition. Wm. C. Brown, Iowa, 459 pages. | | Buchanan, R. E. 1989. Bergey's manual of systemic bacteriology. Volumes I–IV. Wilkins and Wilkins, Baltimore. | | Earl C (1984). "Yellow rain: Thai bees' faeces found". Nature308 (5959): 485. | | Evaluations and Standards Laboratory (July 14, 2008). "Identification of Clostridium Species". pp. 14. | | Gandora V., Gupta R. D., Bhardwaj K. K. R. (1998). "Abundance of Azotobacter in great soil groups of North-West Himalayas". Journal of the Indian Society of Soil Science46 (3): 379–383. | | Grunditz, C; Dalhammar, G (2001). "Development of nitrification inhibition assays using pure cultures of Nitrosomonas and Nitrobacter.".Water research35 (2): 433–40. | | Holt, John G.; Hendricks Bergey, David (1993). R.S. Breed. ed. Bergey's Manual of Determinative Bacteriology (9th ed.). USA: Lippincott Williams and Wilkins. | | J.P. Euzéby (2012) "Rhizobium". List of Prokaryotic names with Standing in Nomenclature (LPSN) | | Jensen H. L. (1954). "The Azotobacteriaceae". Bacteriological Reviews18 (4): 195–214. | | Johnstone D. B. (1955). "Azotobacter Fluorescence". Journal of Bacteriology69 (4):481–482. | | Jones D. H. (1920). "Further Studies on the Growth Cycle of Azotobacter". Journal of Bacteriology5 (4): 325–341. | | Kirk PM, Cannon PF, Minter DW, Stalpers JA. (2008). Dictionary of the Fungi (10th ed.). Wallingford, UK: CABI. pp. 505. | | Kumar R., Bhatia R., Kukreja K., Behl R. K., Dudeja S. S., Narula N. (2007). "Establishment of Azotobacter on plant roots: chemotactic response, development and analysis of root exudates of cotton (Gossypium hirsutum L.) and wheat (Triticum aestivum L.)". Journal of Basic Microbiology47 (5): 436–439. | | Layne J. S., Johnson E. J. (1964). "Natural Factors Involved in the Induction of Cyst Formation in Azotobacter". Journal of Bacteriology87 (3): 684–689. | | Lewis I. M. (1937). "Cell Inclusions and the Life Cycle of Azotobacter". Journal of Bacteriology34 (2): 191–205. | | Maldonado R., Jimenez J., Casadesus J. (1994). "Changes of Ploidy during the Azotobacter vinelandii Growth Cycle". Journal of Bacteriology176 (13): 3911–3919. | | Marsh, K. L., G. K. Sims, and R. L. Mulvaney. 2005. Availability of urea to autotrophic ammonia-oxidizing bacteria as related to the fate of 14C- and 15N-labeled urea added to soil. Biol. Fert. Soil. 42:137-145. | | Martyniuk S., Martyniuk M. (2003). "Occurrence of Azotobacter Spp. in Some Polish Soils". Polish Journal of Environmental Studies12 (3): 371–374. | | Ryan KJ, Ray CG (editors) (2004). Sherris Medical Microbiology (4th ed.). McGraw Hill. | | Socolofsky M. D., Wyss O. (1962). "Resistance of the Azotobacter Cyst". Journal of Bacteriology84: 119–124. | | Yamagata U., Itano A. (1923). "Physiological Study of Azotobacter chroococcum, beijerinckii and vinelandii types". Journal of Bacteriology8 (6): 521–531. |