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Population Dynamics of *Azotobacter chroococcum* in Wheat and Paddy Fields With Different Degrees of Agricultural Intensification in Plains of Northern India

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Abstract: Microbial population in soil is determined by the soil factors, characteristics, composition and environment. Intensification of agriculture in recent years has changed the composition and structure of soil. High input of N. P. K. based fertilizers, pesticides, mechanical tillage, irrigation practices and high yielding crop varieties have changed the soil environment, either inhibiting indigenous microflora or supporting the growth of new type of microflora. The free living nitrogen fixers (*Azotobacter* sp. etc) have been adversely affected by the change. For the purpose of study three sites were selected from wheat and rice fields and different degrees of agricultural intensification were employed. The study of these sites shows that the population of *Azotobacter chroococcum* varied with different degrees of agricultural intensification.

Key words: agricultural intensification, *Azotobacter chroococcum,* population dynamics.

Introduction

Sufficiency in global food supply is dependent on the intensification of agriculture. As intensification occurs, the biological regulation of soil process is altered and often substituted by chemical and mechanical inputs (Tilman *et al*. 2001, Buckley and Schmidt 2003). It is commonly assumed that decline in the biodiversity of the soil biota is due to intensified agricultural practices and may reduce the essential ecosystem functions as well as the ability of agricultural system to withstand periods of stress (McCaig *et al*. 1999, Buckley and Schmidt

2003). However, very little effort has been done to study the relationship between diversity and abundance of soil microorganisms, soil fertility and sustainability.

Among the N_2 fixing bacteria, the rhizobia in symbiosis with legumes are generally most important, although free living N_2 fixers also fix the significant amount of nitrogen under specific condition (Nehra *et al*. 2001). But dinitrogen fixers, particularly *Azotobacter* are greatly affected by practices used in agricultural intensification (Mahajan *et al*. 2007). Some factors associated with agricultural intensification such as increase in salinity or heavy metal pollution in the soil changes the population size of N_2 fixers. Attention has been given to the study of the impact of agricultural intensification on the soil biota in temperate countries but on the other hand attention has not been given under tropical conditions.

The present study was undertaken to investigate the effect of certain agricultural practices responsible for intensification in Indo-Gangetic plains of India, which represent the agro ecosystems of the Tropical countries. Wheat and rice crop were selected for the experiment and investigation was done in two consecutive years.

Materials and Methods

In order to investigate the impact of agricultural intensification on population dynamics of *Azotobacte,r* three sites (villages) with varying degrees of intensification in terms of water resources, chemical and mechanical inputs and crop diversification were selected in Soraon Tehsil of Allahabad district, Uttar Pradesh, India and from each site three farmers fields were selected randomly. To know the history of the selected fields, a group of farmers with different economic status as well as with land holdings were identified at each site and interrogated in a formal way. Soil samples were collected from the selected paddy and wheat fields under aseptic conditions in the plastic bags.

Wheat fields were selected for the present investigation in a rice-wheat cropping pattern, which is the most dominant pattern in Indo-Gangetic plains. Selections of the fields were mainly based on the in-depth interview with farmers about the fields, cropping pattern, fertilization, chemical and mechanical inputs *etc*. On the basis of these inputs, the fields were categorized into highly intensified, moderately intensified and low intensified fields. The fields of the farmers practicing monocropping (wheat/rice) with high yielding varieties, heavy fertilization (200-360 kg/ha urea; 160-240 kg/ha DAP; 140 kg/ha NPK), heavy irrigation and heavy mechanical tillage were categorized as highly intensified. The ones practicing monocropping (wheat + mustard /rice), with high yielding varieties, with moderate fertilization (120-200 kg/ha urea; 80-140 kg/ha DAP), moderate irrigation and mechanical tillage after hiring only once or twice were categorized as moderately intensified fields. Those practicing crop rotation (wheat + mustard + pea /legumes/rice) with local varieties, using very low fertilizer rates (0-60 kg/ha urea) and mold board plough with FYM were categorized as low intensified fields. From each site three sub-sites were selected on the basis of the socio-economic status and land holdings of the farmers. Further from each sub-site three fields with high, moderate and low intensification were selected.

Soil samples were collected randomly from cropped areas of the fields leaving surface soil up to a depth of 5 cm and brought aseptically in the laboratory. The samples of each field were composited and mixed thoroughly. A working sample was drawn from the composite sample and processed for estimating the population of *A. chroococcum* in the non-rhizosphere and rhizosphere soil. Samples of root and non-rhizosphere soil were collected when the crops were at their seedling, vegetative, flowering and fruiting stages. Roots were gently shaken to remove superfluous soil. They were then transferred along with adhering soil particles into a flask containing sterilized distilled water. After thorough shaking of the flask the roots were removed and suitable dilutions were made from the suspension containing rhizosphere soil.

Soil dilution and plate count method of Timonin (1940) was used for estimating the population of *A. chroococcum* in the rhizosphere and non-rhizosphere of different samples. 1/100 dilution, which gave counts between 10-20 colonies per Petri plate were employed. 0.5 ml aliquots from the flask containing final dilution were plated in sterilized Petri plates containing 10 ml of Jensen's agar medium. (Sucrose, 20g; K_2HPO_4, 1g; $MgSO_4$. $7H_2O$, 0.5g; NaCl, 0.5g; $FeSO_4$, 0.1g; Na_2MoO_4, 0.005g; $CaCO_3$, 2g; Agar, 15g; Distilled water, 1000 ml). Five replicates were taken in each case. The dishes were rotated by hand in a broad, swirling motion to distribute the suspension over the medium and incubated at 35±2°C for 24 to 48 hours. The colonies of *A. chroococcum* showing white, spreading, and having a fried egg appearance were marked out and counted. The population of *A. chroococcum / g* oven dry soil was computed on basis of weight of the oven dried soil and the number of colonies appeared on Petri plates.

The isolates were streaked on the Jensen's agar medium. Thereafter, the purified isolates of *A. chroococcum* were grown on the silica gel plates for confirmation test (Becking 1992). The isolated colony was then selected and rechecked for uniform growth by streak method. The colonies of *A. chroococcum* varied in size from 0.5 to 1.5 µm in diameter and became brown black due to pigmentation after 48 hours. Finally, *A. chroococcum* was identified by the method given by the Aquilanti *et al*. (2004).

Temperature, rainfall and relative humidity of Allahabad and adjoining areas were taken from the Meteorological Center Allahabad for the years 2003, 2004 and 2005 (Table 1) and soil biochemical test was done following T. S. B. F. Techniques (1993) to determine the nutrient status of the soil (Table 2).

Tab.1. Temperature, rainfall and relative humidity of Allahabad and adjoining areas for year 2003, 2004 and 2005.

Months	Year 2003				Year 2004				Year 2005			
	Temperature (^{0}C)		Rainfall (cm)	Relative Humidity	Temperature (^{0}C)		Rainfall (cm)	Relative Humidity	Temperature (^{0}C)		Rainfall (cm)	Relative Humidity
	Max.	Min		Max	Min	Max.	Min	Max	Min	Max	Min		Max	Min
JAN	17.87	6.87	0.58	98.83	60.77	19.67	9.35	00	86.06	51.77	23.63	10.10	3.5	94.43	42.96
FEB	26.0	14.25	1.47	92.92	47.21	27.68	12.41	0.17	90.31	35.65	27.03	12.75	1.0	88.67	37.42
MAR	32.81	17.65	0.19	87.32	29.22	36.67	19.12	00	95	7.00	34.4	18.36	5.4	80.03	26.6
APR	40.43	23.9	0.06	64.23	16.96	39.83	23.26	00	92	7.00	39.36	21.6	2.1	47.96	9.5
MAY	41.32	26.90	0.03	53.16	15.64	41.80	27.22	6.0	91	7.00	41.90	25.96	1.6	55.35	14.74
JUN	40.76	29.03	1.96	69.23	9.13	36.26	26.03	6.63	79.06	79.06	42.33	29.83	11.11	52.03	24.0
JUL	40.76	29.03	1.96	69.23	36.73	34.32	26.35	3.39	88.19	55.83	33.16	25.74	9.03	91.74	60.12
AUG	33.29	26.93	5.87	94.03	67.09	33.03	25.70	7.37	92.19	64.93	33.96	26.29	3.08	89.70	61.64
SEP	31.96	26.03	14.83	94.90	71.33	33.36	23.96	1.7	87.7	52.03	33.06	25.66	0.012	91.86	62.8
OCT	31.90	22.12	0.22	92.38	47.58	32.19	18.51	00	88.38	37.96	32.45	22.61	00	89.80	50.45
NOV	29.96	14.16	00.00	90.16	29.1	30.19	11.93	00	92.3	30.33	29.3	11.9	00	84.46	26.33
DEC	24.51	10.06	0.07	98.5	46.01	25.12	9.61	00	95.90	42.22	24.5	9.8	00	93.78	43.12

Tab.2. Average physico-chemical characteristics of soils of rice and wheat fields for the years 2003-04 and 2004-05

Subsites/Degree of Intensification		Rice					Wheat				
		pH	OC %	P_2O_5 kg ha^{-1}	K_2O kg ha^{-1}	N_2 %	pH	OC %	P_2O_5 kg ha^{-1}	K_2O kg ha^{-1}	N_2 %
1	High	6.00	0.48	96	240	0.986	6.10	0.52	95	242	0.958
2	Moderate	6.60	0.72	71	211	0.769	6.90	0.71	77	199	0.759
3	Low	7.00	0.95	40	158	0.549	7.20	0.89	39	125	0.541
1	High	6.12	0.52	100	359	0.866	6.40	0.42	104	302	0.861
2	Moderate	7.30	0.78	60	200	0.799	7.10	0.69	69	195	0.745
3	Low	7.00	0.92	29	149	0.538	7.60	0.89	32	107	0.535
1	High	5.98	0.52	92	282	0.987	6.50	0.51	99	325	0.847
2	Moderate	7.00	0.70	60	222	0.678	7.10	0.75	68	152	0.774
3	Low	6.66	0.99	31	123	0.445	7.70	0.94	35	115	0.421

OC: Organic Carbon; P_2O_5: Phosphate; K_2O: Potash (Potassium fertilizer), N_2: Nitrogen in Soil

Statistical analysis

All the data obtained from different agricultural fields were statistically analyzed using two-way ANOVA with Microsoft Excel 2003 to calculate the MSS. Critical difference (at P=0.05) was calculated by the method given by Panse and Sukhatme (1985).

Results and Discussions

The population of *A. chroococcum* varied according to the degrees of intensification. The population of *A. chroococcum* in the non-rhizospheric soil showed some variation during the survey periods. However these functions may be safely attributed to the variations in the environment and abiotic characters of the soil (Table 1, 2). It was found that in all the fields the rhizospheric population was always higher than the non-rhizospheric soil, at all stages of plant growth. The maximum rhizospheric effect was seen at the flowering stage of both the crops. However, the rhizosphere effect varied with the agricultural intensification and stages of the plant growth, maximum rhizospheric effect being observed at the flowering stage (Khan and Prakash 1982, Brady and Weil 1999, Brimecombe *et al*. 2001).

The data analysis of all the fields shows that maximum population was recorded in the fields having minimum agricultural intensification in terms of chemical and mechanical inputs along with mixed cropping, crop rotation and use of FYM to substitute the chemical fertilizers and reduced tillage both in rice and wheat fields (Table 3-8). The range of population in low intensified rice fields varied from $0.73x10^4$ to $1.45x10^4$ /g oven dry soil in rhizosphere and $0.23x10^4$ to $0.61x10^4$ / g oven dry soil in non-rhizosphere soil. The range of population in low intensified wheat fields varied from $1.52x10^4$ to $3.15x10^4$ / g oven dry soil in rhizosphere and $0.61x10^4$ to $1.15x10^4$ /g oven dry soil in non-rhizospheric soil. The probable cause of the higher population size in the low intensified fields

may be due to low input of chemical fertilizer and use of FYM, mixed cropping, crop rotation and reduced tillage. Several workers have shown that manure application characteristically results in increased biomass, activity and abundance of soil microbes (Martynick and Wagner 1978, Hasebe *et al*. 1985, McGill *et al*. 1986, Ocio *et al*. 1991, Collins *et al*. 1992, Goyal *et al*. 1992). FYM treated plots sustained crop productivity and microbial population at higher level (Mahajan *et al*. 2007). Maximum counts of *A. chroococcum* were observed in treatments where FYM was applied in addition to mineral fertilizers. It may be due to large amount of C source provided by FYM (Mahajan *et al*. 2007), which is required for the proliferation of *A. chroococcum.*

Crop rotation is known to influence beneficially many chemical properties of the soil including organic C content, N supply and transformation, pH and amount and availability of P, K, Ca and Mg (Stevenson and Van Kessel 1996, Monreal *et al*. 1997, Aref and Wander 1998, Arshad *et al*. 1998,). Crop rotations with legumes are especially more beneficial than other crops (Stevenson and Van Kessel 1996, Arshad *et al*. 1998).

Conservation tillage and particularly no tillage reduce soil disturbances, increase organic matter content, improve soil structure, buffer soil temperature and allow soil to catch and hold more melt water. These soils are more biologically active and biologically diverse, have higher nutrient loading capacities and release nutrients continuously (Angers *et al*. 1993, Alvarez *et al*. 1995).

Minimum population of *A. chroococcum* was recorded in highly intensified fields, having maximum chemical and mechanical inputs (Table 3-8). The range of population in highly intensified fields varied from $0.15x10^4$ to $0.64x10^4$ /g oven dry soil in rhizosphere, while non-rhizospheric population ranged from $0.07x10^4$ to $0.20\ x10^4$/g oven dry soil in rice fields while in wheat fields it ranged from $0.42x10^4$ to $2.05x10^4$ in rhizosphere while non-rhizospheric population ranged from $0.21x10^4$ to $0.71x10^4$/g oven dry soil.

Minimum population in these fields was due to the heavy application of nitrogenous and phosphatic fertilizers, heavy mechanical tillage, heavy irrigation and monoculture pattern of cropping. Several workers have shown that heavy use of chemical fertilizers limits the population of soil microbes (Mc Gill *et al*. 1986, Ladd *et al.* 1994, Smolander *et al*. 1994). Effect of nitrogenous fertilizers on the population of *A. chroococcum* was studied by several workers (Roy and Mondal 1968, Bagyaraj and Bhat 1970, Emmimnath and Rangaswami 1971). According to them, the heavy use of nitrogenous fertilizers does not only affect the activity of the microbes but also the population of the diazotrophs. A depressive effect on the population of azotobacters was recorded by the above scientists. It was also found that nitrogenous fertilizers were more effective in the non-rhizosphere than in rhizosphere (Bagyaraj and Bhat 1970, Mandic *et al*. 2005; Mahajan *et al*. 2007).

Phosphorus has stimulatory effect on *A. chroococcum* number in rhizosphere and non-rhizosphere soil (Roy and Mandal 1968) but P fertilizers have indirect effect. P fertilizers often contain significant amounts of cadmium, mercury and lead (Mc Laughlin *et al.* 2000) and long term chronic toxicity due to gradually accumulating metals appears to be far more dangerous to these microorganisms (Ceiller *et al.* 1998).

Heavy tillage practices when applied indiscriminately in dry land cultivation frequently have disastrous effect. Tillage breakdowns soil structure, soil compaction, reduces infiltration, increases evasion and reduces soil organic matter by subsequent degradation of previously protected organic matter (Elliott 1986, de Luca and Keeney 1994, Reicosky *et al.* 1995). Several workers have shown that tillage reduces microbial biomass and number when applied indiscriminately and frequently (Elliot 1986, Angers *et al*. 1993, de Luca and Kenney 1994, Alvarez *et al*. 1995 Calderon *et al*. 2001).

Tab.3. Population of *Azotobacter* in the rhizosphere of rice at different stages of plant growth, cultivated under varying degrees of agricultural intensification at Site I (Population in terms of $1x10^4$ /g oven dry soil, years 2003-2004 and 2004-05).

	Degree of Intensification/ Stages of Plant Growth	**Seedling**		**Vegetative**		**Flowering**		**Fruiting**	
		R	NR	R	NR	R	NR	R	NR
2003-04									
1	DAP (50 kg) + Urea (80 kg) + Monocropping + Mech. Tillage + Tubewell Irrigation	0.25	0.13	0.31	0.17	0.64	0.20	0.55	0.19
2	DAP (35 kg) + Urea (25 kg) + Mech. Tillage +Monocropping + Canal Irrigation	0.60	0.21	0.72	0.30	0.98	0.45	0.84	0.40
3	Urea (15 kg) + Mold board tillage + Crop rotation + FYM + Tubewell irrigation	0.92	0.43	1.02	0.52	1.41	0.62	1.22	0.58
2004-05									
1	DAP (50 kg) + Urea (80 kg) + Mech. Tillage + Monocropping + Irrigation Canal	0.21	0.10	0.29	0.11	0.56	0.18	0.49	0.15
2	DAP(35) Urea (25 kg) + Mech. Tillage + Monocropping + Tubewell Irrigation	0.54	0.20	0.69	0.24	0.89	0.39	0.81	0.34
3	Urea (15 kg) + Mold board tillage + Crop Rotation. + FYM +Tubewell Irrigation	0.90	0.40	1.12	0.54	1.45	0.61	1.23	0.54

Minimum difference required for significance (C. D.) at 5% level: Rhizosphere: 0.0692, Non-rhizosphere: 0.1120

Tab.4. Population of *Azotobacter* in the rhizosphere of rice at different stages of plant growth, cultivated under varying degrees of agricultural intensification at Site II (Population in terms of $1x10^4$ /g oven dry soil, years 2003-2004 and 2004-05).

	Degree of Intensification/ Stages of Plant Growth	Seedling		Vegetative		Flowering		Fruiting	
		R	NR	R	NR	R	NR	R	NR
2003-04									
1	DAP (200 kg) + Urea (320 kg) + Monocropping +Mech. Tillage + Tubewell Irrigation	0.18	0.09	0.22	0.12	0.45	0.16	0.40	0.13
2	DAP (140 kg/h) + Urea (140 kg/ha) + Mech. Tillage + Monocropping + Tubewell Irrigation	0.37	0.12	0.41	0.15	0.68	0.19	0.59	0.16
3	Urea (60 kg/ha) + Mold board tillage + Crop rotation, + FYM +Tubewell irrigation	0.75	0.24	0.80	0.28	1.05	0.35	0.98	0.31
2004-05									
1	DAP (200 kg) + Urea (320 kg) + Monocropping +Mech. Tillage + Tubewell Irrigation	0.15	0.07	0.19	0.09	0.38	0.13	0.36	0.11
2	DAP (140 kg/h) + Urea (140 kg/ha) + Mech. Tillage + Monocropping + Tubewell Irrigation	0.30	0.10	0.38	0.14	0.60	0.16	0.57	0.14
3	Urea (60 kg/ha) + Mold board tillage + Crop rotation, + FYM +Tubewell irrigation	0.73	0.23	0.77	0.25	0.99	0.33	0.92	0.28

Minimum difference required for significance (C. D.) at 5% level: Rhizosphere: 0.1200, Non-rhizosphere: 0.0523

Tab.5. Population of *Azotobacter* in the rhizosphere of rice at different stages of plant growth, cultivated under varying degrees of agricultural intensification at Site III (Population in terms of $1x10^4$ /g oven dry soil, years 2003-2004 and 2004-05).

	Degree of Intensification/ Stages of Plant Growth	Seedling		Vegetative		Flowering		Fruiting	
		R	NR	R	NR	R	NR	R	NR
2003-04									
1	DAP (200 kg/ha) + Urea (320 kg/ha) + Monoculture +Mech. Tillage + Tubewell Irrigation	0.27	0.13	0.30	0.14	0.56	0.18	0.49	0.16
2	DAP (140 kg) + Urea (160 kg) + Mech. Tillage + Monoculture + Canal Irrigation	0.41	0.20	0.48	0.28	0.65	0.32	0.59	0.30
3	Urea (40 kg) + Mold board tillage + Crop rotation, + FYM +Tubewell irrigation	0.84	0.43	0.98	0.48	1.24	0.52	1.10	0.50
2004-05									
1	DAP (200 kg/ha) + Urea (320 kg/ha) + Monoculture +Mech. Tillage + Tubewell Irrigation	0.24	0.11	0.28	0.13	0.53	0.16	0.45	0.14
2	DAP (140 kg) + Urea (160 kg) + Mech. Tillage + Monoculture + Canal Irrigation	0.39	0.18	0.44	0.25	0.61	0.29	0.57	0.26
3	Urea (40 kg) + Mold board tillage + Crop rotation, + FYM +Tubewell irrigation	0.82	0.41	0.95	0.47	1.21	0.52	1.09	0.48

Minimum difference required for significance (C. D.) at 5% level:
Rhizosphere: 0.1079, Non-rhizosphere: 0.0183

Tab.6. Population of *Azotobacter* in the rhizosphere of wheat at different stages of plant growth cultivated under varying degrees of agricultural intensification at Site I (Population in terms of $1x10^4$/g oven dry soil, years 2003-2004 and 2004-05).

	Degree of Intensification/ Stages of Plant Growth	Seedling		Vegetative		Flowering		Fruiting	
		R	NR	R	NR	R	NR	R	NR
2003-04									
1	DAP (240 Kg/h) + Urea (280 Kg/ha)+ NPK (100 Kg/ha)+ Only Wheat + Mech. Tillage + Tube well Irrigation + Monoculture	0.51	0.21	0.92	0.35	1.53	0.50	1.12	0.44
2	DAP 140 Kg /ha+ Urea 140kg/ha + Wheat + Mustard + Mech. Tillage + Tube well Irrigation + Monoculture	1.13	0.42	1.44	0.52	2.13	0.71	1.72	0.66
3	Urea 60 Kg/h + FYM + Wheat + Mustard + Pea +Tube well Irrigation + Mold board tillage + Crop Rotation	1.74	0.72	2.12	0.83	2.81	1.07	2.52	0.93
2004-05									
1	DAP (240 Kg/ha) + Urea (280 Kg/ha)+ NPK (100 Kg/ha)+ Only Wheat + Mech. Tillage + Tube well Irrigation + Monoculture	0.42	0.22	0.73	0.41	1.45	0.54	1.12	0.43
2	DAP 140 Kg/ha+ Urea 140 kg/ha + Wheat + Mustard + Mech. Tillage + Tube well Irrigation + Monoculture	0.81	0.32	1.14	0.52	1.75	0.64	1.44	0.53
3	Urea 60 Kg/ha + FYM + Wheat + Mustard + Pea +Tube well Irrigation + Mold board tillage + Crop Rotation	1.52	0.61	2.05	0.82	2.71	1.00	2.14	0.85

Minimum difference required for significance (C. D.) at 5% level: Rhizosphere: 0.0989, Non-rhizosphere: 0.1214

Tab.7. Population of *Azotobacter* in the rhizosphere of wheat at different stages of plant growth, cultivated under varying degrees of agricultural intensification at Site II (Population in terms of $1x10^4$/g oven dry soil, years 2003-2004 and 2004-05).

	Degree of Intensification/ Stages of Plant Growth	Seedling		Vegetative		Flowering		Fruiting	
		R	NR	R	NR	R	NR	R	NR
2003-04									
1	DAP 220 Kg/ha + Urea 300 Kg/ha + NPK 120 Kg/ha + Wheat + Mech. Tillage + Tube well Irrigation + Monoculture	0.71	0.32	1.11	0.53	1.62	0.61	1.34	0.52
2	DAP 140 Kg/ha + Urea 140 Kg/ha + Wheat + Mustard + Mechanical tillage + Tube well Irrigation + Monoculture	1.12	0.53	1.52	0.63	2.42	0.83	2.14	0.71
3	Urea 60 Kg/h + FYM + Wheat + Mustard +Pea + Tube well Irrigation + Mold board Tillage + Crop Rotation	1.73	0.82	2.34	0.81	3.15	1.06	2.72	0.93
2004-05									
1	DAP 220 Kg/h + Urea 300 Kg/ha + NPK 120 Kg/h + Wheat + Mech. Tillage + Tube well Irrigation + Monoculture	0.52	0.24	0.91	0.42	1.55	0.54	1.22	0.41
2	DAP 140 Kg/ha + Urea 140 Kg/ha + Wheat + Mustard + Mechanical tillage + Tube well Irrigation + Monoculture	1.05	0.42	1.31	0.52	2.23	0.74	1.82	0.66
3	Urea 60 Kg/ha + FYM + Wheat + Mustard +Pea + Tube well Irrigation + Mold board Tillage + Crop Rotation	1.61	0.72	2.14	0.85	2.95	1.06	2.61	0.92

Minimum difference required for significance (C. D.) at 5% level: Rhizosphere: 0.1110, Non-rhizosphere: 0.2120

Tab.8. Population of *Azotobacter* in the rhizosphere of wheat at different stages of plant growth, cultivated under varying degrees of agricultural intensification at Site III (Population in terms of $1x10^4$ /g oven dry soil, years 2003-2004 and 2004-05).

	Degree of Intensification/ Stages of Plant Growth	Seedling		Vegetative		Flowering		Fruiting	
		R	NR	R	NR	R	NR	R	NR
2003-04									
1	DAP (240 Kg/ha) + Urea (280 Kg/ha) + NPK (120 Kg/ha) + Wheat + Mechanical tillage + Tube well Irrigation + Monoculture	0.92	0.44	1.22	0.54	2.05	0.71	1.73	0.65
2	DAP (140 Kg/ha) + Urea (145 Kg/ha) + Wheat + Mustard + Mechanical tillage + Tube well Irrigation + Monoculture	1.31	0.62	1.93	0.75	2.34	0.81	2.02	0.77
3	Urea 40 Kg/ha + FYM + Wheat + Mustard + Pea + Tube well Irrigation + Mold board tillage + Crop Rotation	1.82	0.84	2.15	0.92	2.82	1.14	2.46	1.09
2004-05									
1	DAP (240 Kg/ha) + Urea (280 Kg/h) + NPK (120 Kg/ha) + Wheat + Mechanical tillage + Tube well Irrigation + Monoculture	0.75	0.34	1.16	0.56	1.87	0.65	1.43	0.52
2	DAP (140 Kg/ha) + Urea (145 Kg/ha) + Wheat + Mustard + Mechanical tillage + Tube well Irrigation + Monoculture	1.23	0.55	1.63	0.64	2.25	0.82	1.71	0.63
3	Urea 40 Kg/ha + FYM + Wheat + Mustard + Pea + Tube well Irrigation + Mold board tillage + Crop Rotation	1.62	0.73	1.92	0.81	2.74	1.15	2.14	0.92

Minimum difference required for significance (C. D.) at 5% level: Rhizosphere: 0.1216, Non-rhizosphere: 0.1318

Population vs. chemical inputs

Population of *A. chroococcum* varied with the organic carbon, nitrogen, phosphorus and potassium content of soil in different sites and sub-sites. Comparative data of the population of *A. chroococcum* with reference to % organic carbon, % nitrogen, phosphorus and potassium content in the highly intensified fields of all the sites ranged from 0.15 to 0.64 $x10^4$ /g oven dry soil in the rhizosphere of rice and from 0.42 to $2.05x10^4$ /g oven dry soil in wheat, whereas the non-rhizospheric population ranged from 0.07 to 0.20 x 10^4 /g oven dry soil in rice fields and from 0.22 to 0.71x 10^4/g oven dry soil in wheat fields in the highly intensified fields. Similarly, the population of *A. chroococcum* with reference to % organic carbon, nitrogen, phosphorus and potassium content in the moderately intensified fields of all the sites ranged from 0.81 to 2.42 x 10^4 /g oven dry soil in rice fields and from 0.81 to 2.41x 10^4/g oven dry soil in wheat field whereas the non-rhizospheric population ranged from 0.32 to 0.83 x 10^4 /g oven dry soil in the moderately intensified fields. Comparative data on the population of *A. chroococcum* with reference to nutrient content in the low intensified fields of all the sites ranged from 0.73 to 1.45 x 10^4 /g oven dry soil in rhizosphere of rice and from 1.52 to 3.15x 10^4 /g oven dry soil in the wheat field, while non-rhizospheric population ranged from 0.23 to $0.61x10^4$ /g oven dry soil in rice fields and from 0.61 to $1.14x10^4$ /g oven dry soil in wheat fields (Table 3-8).

Conclusions

Data show that irrespective of the degree of intensification, the highest population of *A. chroococcum* was recorded in the wheat fields with lowest degrees of intensification and the lowest in the rice fields with the highest degrees of intensification. This may be attributed to the changes in the chemical properties of the soil with reference to the land use practices and prevailing water logged condition during the rice crop season.

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DINAMIKA POPULACIJE *Azotobacter chroococcum* U PŠENIČNIM I PIRINČANIM POLJIMA PRI RAZLIČITOM STEPENU INTENZITETA POLJOPRIVREDNIH AKTIVNOSTI PRIMENJENIH U RAVNICAMA SEVERNE INDIJE

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Rezime

Mikrobiološku populaciju u zemljištu odredjuju faktori, osobine i sastav zemljišta, kao i uslovi sredine. Intenzifikacija poljoprivrede poslednjih godina izmenila je sastav i strukturu zemljišta. Velike doze NPK đubriva, pesticida, mašinska obrada zemljišta, navodnjavanje i gajenje visokoprinosnih sorti izmenili su životne uslove u zemljištu, ugrožavajući mikrofloru zemljišta ili podstičući rast novih vrsta mikroorganizama. Ova promena negativno je uticala na slobodne azotofiksatore (*Azotobacter* sp. i dr.). U svrhu istraživanja, odabrane su tri lokacije na pšeničnim i pirinčanim poljima i primenjen je različit intenzitet intenzifikacije poljoprivrede. Ispitivanjem ovih lokacija utvrdjeno je variranje brojnosti *Azotobacter chroococcum* u zavisnosti od stepena intenzifikacije poljoprivrede.