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Changes in biological properties of different soil types of Konkan as influence by FYM application

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Abstract

An incubation study was undertaken in glass house at Department of Horticulture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri during *Kharif*, 2013 to investigate the changes in biological properties of different soil types occurred in the Konkan region *viz.*, coastal alluvial soils, lateritic soils, coastal saline soils, medium black soils, laterite soils, reddish brown soils, coarse shallow soils, acid sulphate (*Morik*) soils and *Manat* soils as affected by FYM application. The experiment was laid out in factorial complete randomized design with soil types as a main factor and FYM application (with and without FYM) as sub-factor comprising eighteen treatments and four periods of observations (30, 60, 90 and 120 DAI) with three replications. The biological properties *viz* CO₂ evolution, microbial biomass carbon, microbial count of bacteria, fungi and actinomycetes were increased with the period of incubation irrespective of different soil types which further enhanced with the application of FYM.

Keywords: Soil types, FYM, CO₂ evaluation and microbial count etc.

Introduction

Konkan region of Maharashtra includes Greater Bombay (603 sq.km), Thane (9558 sq.km), Raigad (7148 sq.km), Ratnagiri (8249 sq. km) and Sindhudurg (5232 sq. km) districts bound by Gujarat in north and Goa in south. It is stretch of 720 km long belt of coastal land and Sahyadri hills with a width varying from 50-60 km. The territory is flanked by Arabian Sea on western side. It is a spread over in between 15° 60' N and 20° 22' N latitude and 72° 39' and 73° 48' longitude.

Materials and Methods

Topography and Parent Material

Topographically, the Konkan coastal lands are platform of Marine denudation raised to form a narrow plain, interrupted by parallel and transverse hills which reach the sea, thus denying the plain of a uniform level. The streams bring about a vast eroded material from their upper reaches and deposit it in lowest zone near the shore line. The coast along the Raigad district appears to be different from Ratnagiri coast, being much indented and suggesting submergence, as confirmed by submerged *khair* forests of Thane district.

In the plains of Raigad, trap rock is found in tabulated masses and irregular shapeless boulders of considerably varying dimensions. The basalt has given rise to fairly thick lateritic particularly in southern part of Raigad and most of the Ratnagiri and Sindhudurg district. The general level of laterization is 150 to 175 meters above mean sea level, but towards east, some higher plateaus also show laterite. The granite and gneisses are exposed in southern part of Sindhudurg district around Kudal (Anonymous 1990) [1].

Climate

Konkan has three seasons i) the summer from March to June ii) the rainy season from June to middle of October and iii) the winter from middle of October to end of February. The average annual rainfall of Thane District is 1808 mm (1574 to 2616 mm), Raigad district is 3128 mm (2083 to 3276 mm) and Ratnagiri and Sindhudurg districts (combined) is 3104 mm (2159 mm to 3886 mm). The maximum rainfall is the received in the month of July. The mean daily temperature is about 20 °C throughout the year.

Month of May is generally hottest, when mean maximum temperature is around 33 °C. During rainy Season, humidity is as high as 90 to 98 per cent. It is least in winter afternoons, when it may come down to about 60 per cent at many places (Anonymous 1990)^[1].

Soil types

The typical topography associated with high rainfall and other climatic conditions has given rise to about nine soil type's viz., coastal alluvial soils, lateritic soils, coastal saline soils, medium black soils, laterite soils, reddish brown soils, coarse shallow soils, acid sulphate (*Morik*) soils and *Manat* soils.

Incubation study

An incubation study was undertaken in the glass house of the Department of Horticulture, College of Agriculture Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, during *kharif* season of 2013 in factorial complete randomized design with nine soil types collected from the representative area of Konkan region as a main factor and FYM application (with and without FYM) as sub-factor comprising eighteen treatments and four periods of observations i.e. 30, 60, 90 and 120 days after incubation (DAI) with three replications.

The plastic pots were first thoroughly cleaned with water and then rinsed with distilled water before filling of the soil. Small quantities of pebbles were put at the bottom of the pots and six kg of soil was filled in each pot. As per the treatment FYM procured from the Dairy Farm, Department of Animal Husbandry and Dairy Science, Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli with 0.62% N, 0.16% and 0.51% K was added and mixed thoroughly. The pots were watered by distilled water regularly by periodic addition of requisite quantity of distilled water so as to maintain the moisture content of soil at field capacity for a period of 120 days. The period of incubation was so chosen as to fit the duration of rice cultivation since all soil types are used for rice cultivation and incubated at room temperature.

In order to understand the changes in biological properties of different soil types of Konkan region and as affected by FYM application, periodical soil samples were collected from each treatment pot at 30, 60, 90 and 120 days after incubation (DAI) and standard analytical methodology as follows.

Results and Discussion

Microbial properties of different soil types as influenced by FYM application

CO₂ evaluation (mg CO₂ g⁻¹) of different soil types as influenced by FYM application

Soil Effect

The mean CO₂ evolution indicates activity of microbes in soil. The CO₂ evolution of different types of soils of Konkan region at various observation period ranged from 155 to 211 mg CO₂ g⁻¹ 190 to 243 mg CO₂ g⁻¹, 160 to 198 mg CO₂ g⁻¹ and 158 to 202 mg CO₂ g⁻¹ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 1).

There was an increase in CO₂ evolution in different soil types with the incubation period over its initial values i.e. at 30 DAI, which continued up to 60 DAI and decreased thereafter. The decrease in CO₂ evolution could be due to deficiency of substrates and nutrients at later periods of incubation (Lal *et al.* 1996)^[11]. In this concerned, Biswas *et*

al. 2007^[5] stated that on incubation, the microbes attached the un-decomposed residues to release higher amount of CO₂. With the decline in substrate availability, the growth and activity of the biomass decline. The small amount of substrate is used for maintenance (Bhattacharyya *et al.* 2001)^[4].

Rise and fall of CO₂ evolution of different soil types of Konkan with and without FYM, as observed herein, are in accordance with Bhattacharyya *et al.* (2001)^[4] in Bankura soils (Typic Haplustalf) (pH 5.2), Canning soils (Typic Endoaquept) (pH 7.2) and Jalpaiguri soils (Aeric Endoaquept) (pH 4.8) of West Bengal.

At 30 DAI, 90 DAI and 120 DAI, *Manat* soils and coarse shallow soils noted the highest mean CO₂ evolution of 214 mg CO₂ g⁻¹, 216 mg CO₂ g⁻¹, and 211 mg mg CO₂ g⁻¹, respectively; while, at 60 DAI *Manat* soils recorded the highest mean CO₂ evolution of 243 mg CO₂ g⁻¹. In case lowest value, the coarse shallow soils, lateritic soils, coastal alluvial soils recorded the lowest value at all observational periods i.e. 155 mg mg CO₂ g⁻¹, 190 mg CO₂ g⁻¹, 160 mg CO₂ g⁻¹, and 158 mg CO₂ g⁻¹, at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively.

FYM Effect

The FYM application, in general, showed higher CO₂ value than no application. This indicated that addition of organics to soil elevate the metabolic status of soil micro-organisms. The FYM addition exerted a stimulating influence on the preponderance of bacteria in soil. This indicated the importance of easily degradable carbonaceous compounds for the proliferation of bacteria population in soil (Mukherjee *et al.* 1990 and Selvi *et al.* 2004)^[14, 18].

Interaction Effect

The interaction between soil types and FYM application was not significant at 30 DAI 90 DAI and 120 DAI. However, at 60 DAI, the interaction was found to be significant. Among interaction at 60 DAI the highest CO₂ evolution 245 mg CO₂ g⁻¹ was registered by *Manat* soil with FYM application (T₉). In case of lowest CO₂ evolution, coarse shallow soils recorded the lowest value of 167 mg CO₂ g⁻¹ at 60 DAI respectively.

Microbial biomass carbon (mg kg⁻¹)

Soil Effect

The mean microbial biomass carbon of different types of soils of Konkan region at various observation period ranged from 2.23 to 3 mg kg⁻¹, 3.55 to 5.25 mg kg⁻¹, 2.40 to 4.24 mg kg⁻¹ and 1.53 to 2.82 mg kg⁻¹ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 2).

There was an increase in microbial biomass carbon in different soil types up to 60 DAI with the incubation period over its initial values, which further decreased from 90 DAI to 120 DAI. The decreasing trend in microbial biomass carbon during the entire period of incubation seemed to be related to the gradual depletion of nutrients at the disposal of the biomass (Bhattacharyya *et al.* 2001)^[4].

The trend in temporal variation of microbial biomass carbon, as observed herein different soil types of Konkan with and without FYM was in conformity with that of Bhattacharyya *et al.* (2001)^[4] in Bankura soils (Typic Haplustalf) (pH 5.2), Canning soils (Typic Endoaquept) (pH 7.2) and Jalpaiguri soils (Aeric Endoaquept) (pH 4.8) of West Bengal.

Table 1: Changes in CO₂ evolution (mg CO₂ g⁻¹) of different soil types of Konkan as influenced by FYM application under incubation study

Treatments (Soil types)		Initial Soil (0 DAI)	Days after incubation (DAI)											
			30 DAI			60 DAI			90 DAI			120 DAI		
			Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T ₁	Coastal alluvial	123	144	169	156	190	199	195	159	176	168	154	161	158
T ₂	Lateritic	144	171	200	185	182	197	190	154	166	160	158	172	165
T ₃	Coastal saline	199	166	192	179	208	225	216	178	190	184	170	176	173
T ₄	Medium black	121	201	221	211	213	223	218	189	206	198	196	208	202
T ₅	Laterite	141	200	218	209	230	238	234	188	190	189	189	195	192
T ₆	Reddish brown	124	174	196	185	197	239	218	187	199	193	180	202	191
T ₇	Coarse shallow	118	144	165	155	167	231	199	208	224	216	202	220	211
T ₈	Acid sulphate	126	176	197	187	185	223	204	191	203	197	192	202	197
T ₉	Manat	120	210	218	214	236	241	243	186	206	196	180	198	189
Mean			176	197	187	202	224	213	182	195	189	180	193	186
			S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)	
Soil type			4.26	16.41		2.96	11.42		6.57	25.28		4.68	17.99	
FYM			2.01	7.73		1.40	5.39		3.09	11.91		2.20	8.48	
Interaction (Soil type x FYM)			6.03	NS		4.19	16.15		9.29	NS		6.61	NS	

FYM Effect

Application of FYM increase soil microbial biomass carbon in comparison to no application of organic matter possibly, provided a supply of good amount of nutrients and the carbon for microbial cell proliferation, which was reflected in higher microbial biomass carbon recorded in this study, as also reported by Ghoshal and Singh (1995) ^[9] and Tripathi *et al.* (2009) ^[24]. The gradual increase in microbial biomass carbon of the enriched soils up to 60 DAI could be attributed to the easily available biodegradable organic matter in FYM which stimulate the biomass (Jenkins on and Ladd 1981 and Bhattacharyya *et al.* 2001) ^[4] or to the incorporation of exogenous micro-organisms (Perucci 1992) ^[17]. The decreasing trend, thereafter, seemed to be related to the "protective capacity" of soil for biomass (Sparling 1985) ^[20]. Biomass generated in excess of that capacity, is automatically killed or Probably the same phenomenon also occurred here, significantly higher microbial biomass carbon levels of the enriched soils, in comparison to the control, at all stages of incubation indicated that FYM enrichment in soil would result in the improvement of soil

quality component. It is on record (Statton *et al.* 1995) ^[21] that the most dramatic influence of compost addition to soil takes place on marginal soils with low organic matter and plant nutrients. Same phenomenon also took place in coastal saline and acid sulphate soils.

In three different soils *i.e.* Bankura soils (Typic Haplustalf) (pH 5.2), Canning soils (Typic Endoaquept) (pH 7.2) and Jalpaiguri soils (Aeric Endoaquept) (pH 4.8) of West Bengal, Bhattacharyya *et al.* (2001) ^[4] found increase in soil microbial biomass carbon with organic matter application.

Interaction Effect

At 30 DAI, 60 DAI and 120 DAI, the interaction between soil types and FYM application was non-significant. However, at 90 DAI the interaction was found to be significant. Among interaction at 90 DAI the highest biomass carbon 441 mg kg⁻¹, was registered by coastal saline soil with FYM application (T₃). In case of lowest biomass carbon, acid sulphate soils recorded the lowest value of 2.34 mg kg⁻¹, at 90 DAI.

Table 2: Changes in biomass carbon (mg kg⁻¹) of different soil types of Konkan as influenced by FYM application under incubation study

Treatments (Soil types)		Initial Soil (0 DAI)	Days after incubation (DAI)											
			30 DAI			60 DAI			90 DAI			120 DAI		
			Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T ₁	Coastal alluvial	8.44	2.75	3.08	2.91	4.88	4.98	4.93	2.67	3.13	2.90	1.67	2.03	1.85
T ₂	Lateritic	6.33	3.22	3.33	3.28	4.49	4.82	4.65	4.13	4.35	4.24	2.64	2.74	2.69
T ₃	Coastal saline	0.52	2.27	3.10	2.68	3.48	3.61	3.55	3.77	4.41	4.09	1.65	1.70	1.68
T ₄	Medium black	5.54	2.99	3.15	3.07	4.07	4.27	4.17	3.04	4.10	3.57	1.66	1.76	1.71
T ₅	Laterite	2.11	2.16	2.29	2.23	5.11	5.39	5.25	2.50	2.65	2.58	2.37	2.58	2.48
T ₆	Reddish brown	4.75	2.48	2.64	2.56	5.05	5.19	5.12	2.84	3.04	2.94	2.68	2.95	2.82
T ₇	Coarse shallow	5.54	2.52	2.79	2.66	4.26	4.60	4.43	2.75	2.89	2.82	2.52	2.68	2.60
T ₈	Acid sulphate	6.86	2.30	2.44	2.37	4.19	4.29	4.24	2.34	2.46	2.40	1.45	1.62	1.53
T ₉	Manat	8.97	2.19	2.28	2.24	4.05	4.12	4.09	2.64	3.09	2.86	2.57	2.76	2.67
Mean			2.54	2.79	2.66	4.40	4.58	4.49	2.97	3.35	3.16	2.13	2.31	2.22
			S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)	
Soil type			0.07	0.07		0.10	0.38		0.08	0.38		0.07	0.28	
FYM			0.03	0.12		0.04	0.18		0.04	0.15		0.03	0.13	
Interaction (Soil type x FYM)			0.09	NS		0.14	NS		0.12	0.49		0.10	NS	

Microbial count of bacteria (cfu x 10⁴)**Soil Effect**

The trend of variation in microbial count of bacteria in different types of soils of Konkan with and without FYM

showed that the values increased with the time of incubation and the highest values were recorded at 60 DAI. After 60 DAI, the microbial count of bacteria in different types of soils started declining to reach the lowest values at 120 DAI.

At 30 DAI, 90 DAI and 120 DAI coastal alluvial and medium black soils noted the highest mean bacteria of $267 \text{ cfu} \times 10^4$, $306 \text{ cfu} \times 10^4$ and $256 \text{ cfu} \times 10^4$, respectively; while at 60 DAI medium black soil recorded the highest mean bacteria of $315 \text{ cfu} \times 10^4$. In case lowest value, the reddish brown soils, lateritic and coastal alluvial soils recorded the lowest value at all observational periods i.e. $145 \text{ cfu} \times 10^4$, $119 \text{ cfu} \times 10^4$, $207 \text{ cfu} \times 10^4$ and $202 \text{ cfu} \times 10^4$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively.

FYM Effect

Application of FYM significantly increased the microbial count of bacteria over no application. This is possible since most of the soil microorganisms are chemo-heterotrophy, which require organic source of carbon as food and oxidation of organic substances provided energy Bedi *et al.* (2009) ^[2, 3] in acid Alfisols soils and Mhalshi (2013) ^[13] in lateritic soils of Konkan also found increase in microbial

count of bacteria with organic matter application. Lal *et al.* (1996) ^[11] found increase in the microbial count due to application of FYM under incubation in Alfisol of Bihar.

Interaction Effect

The interaction between soil types and FYM application was not significant at 30 DAI. However, at 30 DAI, 60 DAI and 120 DAI, the interaction was found to be significant. Among interaction, at 60 DAI the highest bacteria ($323 \text{ cfu} \times 10^4$) was registered by medium black soil with FYM application (T_1) and at 30 DAI and 120 day coastal alluvial soils and medium black soil with FYM application registered the highest bacteria of $146 \text{ cfu} \times 10^4$ and $285 \text{ cfu} \times 10^4$, respectively. In case of lowest bacteria, reddish brown, lateritic and Manat recorded the lowest value of $69 \text{ cfu} \times 10^4$, $187 \text{ cfu} \times 10^4$ and $210 \text{ cfu} \times 10^4$ at 30 DAI, 60 DAI and 120 DAI, respectively.

Table 3: Changes in bacteria (cfu X 10⁴) of different soil types of Konkan as influenced by FYM application under incubation study

Treatments (Soil types)		Initial Soil (0 DAI)	Days after incubation (DAI)											
			30 DAI			60 DAI			90 DAI			120 DAI		
			Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T ₁	Coastal alluvial	6	95	146	267	211	230	221	194	220	207	187	217	202
T ₂	Lateritic	9	117	129	251	210	228	219	202	217	209	194	211	203
T ₃	Coastal saline	6	98	125	237	244	307	275	230	300	265	218	240	229
T ₄	Medium black	11	70	89	169	307	323	315	296	317	306	228	285	256
T ₅	Laterite	8	105	115	225	217	251	234	203	237	220	191	215	203
T ₆	Reddish brown	10	69	74	145	257	265	261	237	253	245	217	247	232
T ₇	Coarse shallow	9	117	123	243	253	307	280	213	251	232	207	213	210
T ₈	Acid sulphate	5	99	105	206	232	303	268	217	247	232	203	213	208
T ₉	Manat	8	79	95	182	233	290	262	200	257	228	187	232	210
Mean			94	111	214	240	278	259	221	255	238	204	230	217
			S.E.±		C.D.(P= 0.01)	S.E.±		C.D.(P= 0.01)	S.E.±		C.D.(P= 0.01)	S.E.±		C.D.(P= 0.01)
Soil type			3.62		13.07	4.82		16.64	7.04		27.09	3.82		14.69
FYM			1.84		6.58	2.04		7.84	3.32		12.77	1.80		6.92
Interaction (Soil type x FYM)			5.14		19.76	6.12		23.53	9.96		NS	5.40		20.78

Microbial count of fungi (cfu x 10³) of different soil types as influenced by FYM application:

Soil Effect

The mean microbial count of fungi of different types of soils of Konkan region at various observation period ranged from 57 to 97 $\text{cfu} \times 10^3$, 110 to 269 $\text{cfu} \times 10^3$, 113 to 230 $\text{cfu} \times 10^3$ and 95 to 219 $\text{cfu} \times 10^3$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 4).

The trend of variation in microbial count of fungi in different types of soils of Konkan with and without FYM showed that the values increased with the time of incubation and the highest values were recorded at 60 DAI. After 60 DAI, the microbial count of bacteria in different types of soils started decline to reach the lowest values at 120 DAI. The initial increase may be due to ambient and favorable temperature for growth of fungi and with the increase in temperature, the fungal population to be deactivate.

At 30 DAI, 90 DAI and 120 DAI coastal, alluvial soils, lateritic soils noted the highest mean fungi of $97 \text{ cfu} \times 10^3$, $230 \text{ cfu} \times 10^3$ and $219 \text{ cfu} \times 10^3$, respectively; while at 60 DAI laterite soils recorded the highest mean fungi of $269 \text{ cfu} \times 10^3$. In case of lowest value, the Manat soils, medium black and coastal alluvial soils recorded the lowest value at all observational periods i.e. $57 \text{ cfu} \times 10^3$, $110 \text{ cfu} \times 10^3$, 113

$\text{cfu} \times 10^3$ and $95 \text{ cfu} \times 10^3$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively.

FYM Effect

The microbial count of fungi of different types of soils of Konkan region at various observation period without FYM ranged from 45 to 85 $\text{cfu} \times 10^3$, 103 to 255 $\text{cfu} \times 10^3$, 101 to 227 $\text{cfu} \times 10^3$ and 71 to 208 $\text{cfu} \times 10^3$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively and with FYM ranged from 70 to 111 $\text{cfu} \times 10^3$, 117 to 283 $\text{cfu} \times 10^3$, 117 to 233 $\text{cfu} \times 10^3$, and 109 to 230 $\text{cfu} \times 10^3$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 4).

Since most of the soil microorganisms are chemo-heterotrophs, which require organic source of carbon as food and oxidation of organic substances provided energy (Bedi *et al.* 2009) ^[2, 3], application of FYM significantly increased the microbial count of fungi over no application. Bedi *et al.* (2009) ^[2, 3] in acid Alfisols soils and Mhalshi (2013) ^[13] in lateritic soils of Konkan also found increase in microbial count of fungi with organic matter application. Lal *et al.* (1996) ^[11] found increase in the microbial count due to application of FYM under incubation in Alfisol of Bihar.

Table 4: Changes in fungi (cfu X 10³) of different soil types of Konkan as influenced by FYM application under incubation study

Treatments (Soil types)		Initial Soil (0 DAI)	Days after incubation (DAI)											
			30 DAI			60 DAI			90 DAI			120 DAI		
			Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T ₁	Coastal alluvial	5	85	109	97	103	149	126	101	135	118	71	119	95
T ₂	Lateritic	7	67	93	80	166	187	176	148	157	153	137	150	143
T ₃	Coastal saline	4	53	87	70	199	205	202	151	165	158	142	156	149
T ₄	Medium black	8	56	77	67	103	117	110	109	117	113	95	109	102
T ₅	Laterite	7	63	81	72	255	283	269	227	233	230	207	230	219
T ₆	Reddish brown	6	59	85	72	224	239	231	213	228	221	208	218	213
T ₇	Coarse Shallow	6	58	99	78	225	245	235	143	167	155	129	139	134
T ₈	Acid sulphate	8	81	111	96	201	212	207	201	220	211	189	206	197
T ₉	Manat	7	45	70	57	215	229	222	119	128	124	105	123	114
Mean			63	90	77	188	207	198	157	172	165	143	161	152
			S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)	
Soil type			3.95	15.20		4.20	16.16		5.36	20.23		6.97	26.69	
FYM			1.86	7.16		1.98	7.62		2.52	9.72		3.27	2.58	
Interaction (Soil type x FYM)			5.59	NS		5.94	NS		7.58	NS		9.81	NS	

Interaction Effect

The interaction between soil types and FYM application was not significant at 30 DAI, 60 DAI, 90 DAI and 120 DAI.

Microbial count of actinomycetes (cfu x 10⁴) of different soil types as influenced by FYM application**Soil Effect**

The mean microbial count of actinomycetes of different types of soils of Konkan region at various observation period ranged from 34 to 57 cfu x 10⁴, 93 to 168 cfu x 10⁴, 121 to 181 cfu x 10⁴ and 99 to 187 cfu x 10⁴ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 5).

The trend of variation in microbial count of actinomycetes in different types of soils of Konkan with and without FYM showed that the values increased with the time of incubation and the highest values were recorded at 90 DAI. After 90 DAI, the microbial count of actinomycetes in different types of soils started decline to reach the low values at 120 DAI.

FYM Effect

The microbial count of actinomycetes of different types of soils of Konkan region at various observation period without FYM ranged from 24 to 42 cfu x 10⁴, 51 to 147 cfu x 10⁴, 103 to 162 cfu x 10⁴ and 52 to 97 cfu x 10⁴ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively and with FYM

ranged from 43 to 73 cfu x 10⁴, 133 to 84 cfu x 10⁴, 138 to 208 cfu x 10⁴ and 113 to 205 cfu x 10⁴ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 5).

Since most of the soil microorganisms are chemo-heterotrophs, which require organic source of carbon as food and oxidation of organic substances provided energy (Bedi *et al.* 2009) [2, 3], application of FYM significantly increased the microbial count of actinomycetes over no application. Bedi *et al.* (2009) [2, 3] in acid Alfisols soils and Mhalshi (2013) [13] in lateritic soils of Konkan also found increase in microbial count of actinomycetes with organic matter application.

Interaction Effect

The interaction between soil types and FYM application was not significant at 30 DAI and 90 DAI. However, at 60 DAI and 120 DAI the interaction was found to be significant. Among interaction at 60 DAI and 120 DAI, the highest actinomycetes (184 cfu x 10⁴ and 205 cfu x 10⁴, respectively) was registered by laterite (T₅) and acid sulphate soils (T₈) with FYM application. In case of lowest actinomycetes, coastal alluvial soils and reddish brown soils recorded the lowest value of 51 cfu x 10⁴ and 52 cfu x 10⁴ at 60 DAI and 120 DAI, respectively.

Table 5: Changes in actinomycetes (cfu X10⁴) of different soil types of Konkan as influenced by FYM application under incubation study

Treatments (Soil types)		Initial Soil (0 DAI)	Days after incubation (DAI)											
			30 DAI			60 DAI			90 DAI			120 DAI		
			Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T ₁	Coastal alluvial	4	25	69	47	51	135	93	103	139	121	85	113	99
T ₂	Lateritic	6	33	61	47	103	161	132	131	159	145	77	136	106
T ₃	Coastal saline	4	26	64	45	126	159	143	162	171	167	97	151	124
T ₄	Medium black	7	24	43	34	107	146	126	121	152	137	85	171	128
T ₅	Laterite	6	31	65	48	145	184	165	155	190	172	73	157	115
T ₆	Reddish brown	6	29	49	39	147	190	168	153	208	181	52	154	103
T ₇	Coarse shallow	5	35	61	48	115	133	124	124	138	131	78	125	102
T ₈	Acid sulphate	5	42	73	57	86	138	112	126	167	147	89	205	147
T ₉	Manat	9	33	65	49	130	147	138	143	160	151	71	201	136
Mean			31	61	46	112	155	133	135	165	150	79	157	118
			S.E.±	C.D. (P= 0.01)		S.E.±	C.D. (P= 0.01)		S.E.±	C.D. (P= 0.01)		S.E.±	C.D. (P= 0.01)	
Soil type			2.97	11.43		4.80	18.46		6.88	26.47		3.43	13.21	
FYM			1.40	5.39		2.26	8.7		3.24	12.48		1.61	6.22	
Interaction (Soil type x FYM)			4.20	NS		6.78	13.13		9.73	NS		4.85	18.68	

Dehydrogenase activity ($\mu\text{g TPF g}^{-1}$) of different soil types as influenced by FYM application

Dehydrogenase is considered to be an indicator of total microbial activity (Skujins 1973) ^[22], on which the urease activity depends predominantly (Cassida 1977 and Shilpashree and Kotur 2009) ^[19].

Soil Effect

The mean dehydrogenase activity of different types of soils of Konkan region at various observation period ranged from 42 to 147 $\mu\text{g TPF g}^{-1}$, 42 to 152 $\mu\text{g TPF g}^{-1}$, 43 to 162 $\mu\text{g TPF g}^{-1}$ and 45 to 163 $\mu\text{g TPF g}^{-1}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 6).

At 30 DAI, 60 DAI and 90 DAI medium black soils noted the highest mean dehydrogenase activity of 147 $\mu\text{g TPF g}^{-1}$, 152 $\mu\text{g TPF g}^{-1}$, and 162 $\mu\text{g TPF g}^{-1}$, respectively; while, at 120 DAI medium black soils recorded the highest mean

dehydrogenase activity of 163 $\mu\text{g TPF g}^{-1}$. In case of lowest value, the course shallow soils and coastal alluvial soils recorded the lowest value at all observational periods i.e. 42 $\mu\text{g TPF g}^{-1}$, 42 $\mu\text{g TPF g}^{-1}$, 43 $\mu\text{g TPF g}^{-1}$ and 45 $\mu\text{g TPF g}^{-1}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively.

FYM Effect

Application of FYM significantly increased the dehydrogenase activity over no application at all observation periods. In this connection, Praveen Kumar *et al.* (2007) ^[10] reported that the activities of dehydrogenase are associated with the organic matter content in the soil. In their study they found that the activities of dehydrogenase decreased markedly with soil depth in different rotation as well as in the tilled and untilled fields and this decrease in activities with depth was associated with decrease in organic matter content.

Table 6: Changes in dehydrogenase ($\mu\text{g TPF g}^{-1}$ soil hr⁻¹) of different soil types of Konkan as influenced by FYM application under incubation study

Treatments (Soil types)		Initial Soil (0 DAI)	Days after incubation (DAI)											
			30 DAI			60 DAI			90 DAI			120 DAI		
			Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T ₁	Coastal alluvial	41	52	76	64	42	44	43	41	44	43	44	46	45
T ₂	Lateritic	75	72	75	74	68	76	72	73	76	75	72	75	74
T ₃	Coastal saline	85	74	89	81	83	84	83	76	78	77	80	84	82
T ₄	Medium black	150	143	151	147	150	154	152	161	163	162	161	164	163
T ₅	Laterite	124	112	130	121	109	128	119	117	130	124	118	129	123
T ₆	Reddish brown	75	85	93	89	82	84	83	83	89	86	73	75	74
T ₇	Coarse shallow	42	41	43	42	41	42	42	42	58	50	43	55	49
T ₈	Acid sulphate	77	65	77	71	55	75	65	73	73	73	77	94	85
T ₉	Manat	122	125	127	126	127	128	128	128	129	128	93	127	110
Mean			85	95	90	84	90	87	88	93	90	42	94	89
			S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)	
Soil type			4.38	16.88		2.08	8.02		2.45	9.45		2.93	11.27	
FYM			2.06	7.95		0.98	3.78		1.15	4.45		1.38	5.31	
Interaction (Soil type x FYM)			6.20	NS		2.95	11.34		3.47	NS		4.14	15.94	

Interaction Effect

The interaction between soil types and FYM application was not significant at 30 DAI and 90 DAI. However, at 60 DAI and 120 DAI, the interaction was found to be significant. Among interaction at 60 DAI and 120 DAI, the highest dehydrogenase activity of 154 $\mu\text{g TPF g}^{-1}$ and 164 $\mu\text{g TPF g}^{-1}$, respectively, was registered by medium black soil with FYM application (T₄). In case of lowest dehydrogenase activity, course shallow soils recorded the lowest value of 41 $\mu\text{g TPF g}^{-1}$ and 43 $\mu\text{g TPF g}^{-1}$ at 60 DAI and 120 DAI, respectively.

Urease activity ($\mu\text{g urea/g dry soil/hr}$) of different soil types as influenced by FYM application

The time required for hydrolyzing half the quantity of applied urea is referred as urease activity. The activity of urease enzyme in soils significantly influence hydrolysis of

urea and further transformation like nitrification and volatilization losses of ammonia. Urease has a definite role in N use efficiency of urea applied to crops, especially if applied to surface or partially incorporated (Shilpashree and Kotur 2009) ^[19].

Soil Effect

The mean urease activity of different types of soils of Konkan region at various observation period ranged from 14.99 to 22.06 $\mu\text{g urea/g dry soil/hr}$, 20.66 to 33.40 $\mu\text{g urea/g dry soil/hr}$, 12.99 to 19.23 $\mu\text{g urea/g dry soil/hr}$ and 5.16 to 12.06 $\mu\text{g urea/g dry soil/hr}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 7).

The increased enzyme activities of soils, even after the fall of microbial biomass, seemed to be related to active enzymes within dead cells, associated cell fragments and activity of living cell (Skujin 1973) ^[22].

Table 7: Changes in Urease activity ($\mu\text{g/g dry soil/hr}$) of different soil types of Konkan as influenced by FYM application under incubation study

Treatments (Soil types)		Initial Soil (0 DAI)	Days after incubation (DAI)											
			30 DAI			60 DAI			90 DAI			120 DAI		
			Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T ₁	Coastal alluvial	7.22	18.46	25.66	22.06	28.13	38.66	33.40	14.80	23.66	19.23	8.46	15.66	12.06
T ₂	Lateritic	6.03	17.66	21.33	19.50	28.00	32.33	30.16	14.66	20.00	17.33	7.66	11.33	9.50
T ₃	Coastal saline	3.63	14.46	17.66	16.06	24.80	28.66	26.73	11.46	16.33	13.89	4.46	7.66	6.06
T ₄	Medium black	4.24	15.51	18.99	17.25	25.84	29.66	27.75	12.84	16.33	14.58	5.84	8.99	7.42
T ₅	Laterite	7.02	16.96	20.33	18.64	27.29	30.33	28.81	15.29	18.99	17.14	7.29	10.33	8.81
T ₆	Reddish brown	4.82	15.33	19.66	17.49	25.66	30.99	28.33	13.66	17.66	15.66	5.66	9.66	7.66
T ₇	Coarse shallow	3.20	14.33	18.99	16.66	24.66	19.66	22.16	11.66	17.33	14.49	4.66	8.99	6.83
T ₈	Acid sulphate	2.60	13.33	16.66	14.99	23.66	17.66	20.66	10.99	14.99	12.99	3.66	6.66	5.16
T ₉	Manat	7.00	18.53	22.33	20.43	28.86	33.66	31.26	16.86	19.66	18.26	8.86	12.33	10.59
Mean			15.06	20.18	18.12	26.32	29.07	27.69	13.58	18.33	15.95	6.28	10.18	8.23
			S.E. $\pm$	C.D.(P= 0.01)		S.E. $\pm$	C.D.(P= 0.01)		S.E. $\pm$	C.D.(P= 0.01)		S.E. $\pm$	C.D.(P= 0.01)	
Soil type			0.22	0.88		0.47	1.80		0.47	1.83		0.18	0.70	
FYM			0.10	0.41		0.22	0.85		0.22	0.86		0.08	0.33	
Interaction (Soil type x FYM)			0.32	1.24		0.66	2.55		0.67	2.59		0.26	1.00	

The trend of variation in urease activity in different types of soils of Konkan with and without FYM showed that the values increased with the time of incubation and the highest values were recorded at 60 DAI. After 60 DAI, the urease activity in different types of soils started decline to reach the low values at 120 DAI, which may be due to increase in temperature. Also observed decline in urease activity of Pasture and Hill soils of Orissa when the temperature was increased beyond 47 °C. Studies on urease activity in medium black, coastal saline and lateritic soils of Konkan done by Chavan (2002) [8] indicated increase in urease activity of all soils when the temperature was increased from 37 to 57 °C and then it declines rapidly with increase in temperature to 67 °C. Further, Chavan (2002) [8] noted that the increase in urease activity up to 57 °C might be due to higher activation of soil urease and subsequent decline at 67 °C might be due to partial inactivation of soil urease enzyme. Bremner and Mulvaney (1978) [6] while reviewing effect of temperature on urease activity of soils stated that at higher temperatures (65 to 90 °C) the urease activity is partially inactivated, but not completely destroyed. But, soil heating to a temperature of 105 °C, there is complete inactivation of soils urease.

The trend in temporal variation of urease activity, as observed herein different soil types of Konkan with and without FYM was in conformity with that of Bhattacharyya *et al.* (2001) [4] in Bankura soils (Typic Haplustalf) (pH 5.2), Canning soils (Typic Endoaquept) (pH 7.2) and Jalpaiguri soils (Aeric Endoaquept) (pH 4.8) of West Bengal. The similar trend of initial increase and thereafter decrease of urease activity under incubation was also reported by Lal *et al.* (1996) [11] in Alfisol of Bihar.

At 30 DAI, 90 DAI and 120 DAI coastal alluvial soils noted the highest mean urease activity of 22.06 $\mu\text{g urea/g dry soil/hr}$, 19.23 $\mu\text{g urea/g dry soil/hr}$ and 12.06 $\mu\text{g urea/g dry soil/hr}$, respectively; while at 60 DAI, coastal alluvial soils recorded the highest mean urease activity of 33.40 $\mu\text{g urea/g dry soil/hr}$. In case lowest value, the acid sulphate soils recorded the lowest value at all observational periods i.e. 14.19 $\mu\text{g urea/g dry soil/hr}$, 20.66 $\mu\text{g urea/g dry soil/hr}$, 12.99 $\mu\text{g urea/g dry soil/hr}$ and 5.16 $\mu\text{g urea/g dry soil/hr}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively.

FYM Effect

The urease activity of different types of soils of Konkan region at various observation period without FYM ranged from 13.33 to 18.53 $\mu\text{g urea/g dry soil/hr}$, 23.66 to 28.86 $\mu\text{g urea/g dry soil/hr}$, 10.99 to 16.86 $\mu\text{g urea/g dry soil/hr}$ and 3.66 to 8.86 $\mu\text{g urea/g dry soil/hr}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively and with FYM ranged from 16.66 to 25.66 $\mu\text{g urea/g dry soil/hr}$, 17.66 to 38.66 $\mu\text{g urea/g dry soil/hr}$, 14.99 to 23.66 $\mu\text{g urea/g dry soil/hr}$ and 6.66 to 15.66 $\mu\text{g urea/g dry soil/hr}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI respectively (Table 7).

Application of FYM significantly increased the urease activity over no application at all observation periods. Lal *et al.* (1996) [11] found increase in urease activity due to application of FYM under incubation in Alfisol of Bihar. Soils enzyme activities may be increased by the incorporation of organic material in the soil (Nannipieri *et al.* 1983) [15]. This increased activity has generally been attributed to increased microbial biomass resulting from organic matter enrichment in the soil (Praveen Kumar *et al.* 2007) [10]. This increase in activity may be due to incorporation and protection to the enzyme fraction upon increase in the soil humus content (Martens *et al.* 1992) [12].

Interaction Effect

The interaction between soil types and FYM application was significant at 30 DAI, 60 DAI, 90 DAI and 120 DAI. Among interaction at 30 DAI, 60 DAI, 90 DAI and 120 DAI, the highest was registered by coastal alluvial soil with FYM application (T₁) 25.66 $\mu\text{g urea/g dry soil/hr}$, 38.66 $\mu\text{g urea/g dry soil/hr}$, 23.66 $\mu\text{g urea/g dry soil/hr}$ and 15.66 $\mu\text{g urea/g dry soil/hr}$, respectively. In case of lowest, acid sulphate soils recorded the lowest value of 13.33 $\mu\text{g urea/g dry soil/hr}$, 20.66 $\mu\text{g urea/g dry soil/hr}$, 10.19 $\mu\text{g urea/g dry soil/hr}$ and 3.66 $\mu\text{g urea/g dry soil/hr}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively.

In an incubation study the urease activity of different soils of Konkan, the urease activity of coastal alluvial soil was the lowest (8.4 hr.) due to its coarse texture (72.96 % sand). It was highest in case of coastal saline soil (4.4 hr.) followed by Manat (5.2 hr.) and medium black (5.8 hr.) soils. These soils are almost neutral in reaction and containing higher

proportion of silt and clay fraction. In comparison to these soils, the urease activity of lateritic soil was low (7.0 hr.), which was attributed to its acidic soil reaction (Anonymous 1990) [1].

Appreciable activity of ureolytic enzymes closely related to organic matter content in these soils indicated that the N use efficiency of urea applied to crops can be substantially reduced if not adequately incorporated or unless the slow-release forms or neem oil / product blended /coated urea are used in these soils.

Phosphatase activity ($\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$) of different soil types as influenced by FYM application

Phosphatases are the indicators of rate of hydrolysis of the organic P in the soil (Tarafdar 2001) [23]. Moreover, phosphatase measured in soils reflect the activity of enzymes bound to soil colloids and humic substances, free phosphatases in the soil solution and phosphatases associated with living and dead plant debris or microbial cells (Nannipieri *et al.* 1990) [16].

Soil Effect

The mean phosphates activity of different types of soils of Konkan region at various observation period ranged from 179 to 773 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$, 642 to 801 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$, 615 to 868 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ and 659 to 930 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 8).

The trend of variation in phosphates activity in different types of soils of Konkan with and without FYM showed that

the values increased with the time of incubation and the highest values were recorded at 60 DAI. After 60 DAI, the phosphates activity in different types of soils started decline at 90 DAI, which further increased at 120 DAI. The increased enzyme activities of soils, even after the fall of microbial biomass, seemed to be related to active enzymes within dead cells, associated cell fragments and activity of living cell (Skujing 1973) [22]. The persistence of phosphates activity after attaining their peak values seemed to reflect the differential behavior of "protective capacity" of soils in respect of phosphates activity or it might be the continued production of phosphatase by the existing micro-organisms (Bhattacharyya *et al.* 2001) [4].

The trend in temporal variation of phosphatase activity, as observed herein different soil types of Konkan with and without FYM was in conformity with that of Bhattacharyya *et al.* (2001) [4] in Bankura soils (Typic Haplustalf) (pH 5.2), Canning soils (Typic Endoaquept) (pH 7.2) and Jalpaiguri soils (Aeric Endoaquept) (pH 4.8) of West Bengal. The similar trend of initial increase and thereafter decrease of phosphatase activity under incubation was also reported by Lal *et al.* (1996) [11] in Alfisol of Bihar.

At 30 DAI and 90 DAI, *Manat* soils recorded the highest mean phosphates activity of 773 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ and 868 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$, respectively and at 60 DAI and 120 DAI reddish brown soils recorded the highest mean phosphates activity of 801 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ and 930 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$. In case lowest value, the coastal alluvial soils at 30 DAI and 120 DAI, recorded the lowest value of 579 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ and 659

Table 8: Changes in Phosphates activity ($\mu\text{g PNP g dry wt/hr}$) of different soil types of Konkan as influenced by FYM application under incubation study

Treatments (Soil types)		Initial Soil (0 DAI)	Days after incubation (DAI)											
			30 DAI			60 DAI			90 DAI			120 DAI		
			Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
T ₁	Coastal alluvial	353	526	632	579	663	682	673	632	684	658	651	667	659
T ₂	Lateritic	378	579	684	632	546	649	597	614	649	632	667	775	721
T ₃	Coastal saline	454	611	632	621	649	684	667	651	825	738	844	861	853
T ₄	Medium black	404	538	651	595	772	807	789	740	842	791	789	879	834
T ₅	Laterite	378	611	649	630	647	675	661	579	651	615	758	768	763
T ₆	Reddish brown	303	758	770	764	775	826	801	844	877	861	912	947	930
T ₇	Coarse shallow	277	614	649	632	733	751	742	737	861	799	859	895	877
T ₈	Acid sulphate	328	632	707	669	649	684	667	809	859	834	825	877	851
T ₉	Manat	480	737	809	773	598	686	642	842	895	868	825	842	833
Mean			623	687	655	670	716	693	716	794	755	792	835	813
			S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)		S.E.±	C.D.(P= 0.01)	
Soil type			19.71	75		15.11	58.11		25.34	97.47		20.85	80.19	
FYM			9.29	35.74		7.12	27.39		11.94	45.95		9.83	37.80	
Interaction (Soil type x FYM)			27.88	NS		21.36	NS		35.84	NS		29.49	NS	

$\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$, respectively. *Manat* soils and laterite soils recorded the lowest value of 642 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ and 615 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ at 30 60 DAI and 90 DAI, respectively.

FYM Effect

The phosphates activity of different types of soils of Konkan region at various observation period without FYM ranged from 526 to 758 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$, 546 to 775 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$, 579 to 844 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ and 651 to 859 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively and with FYM ranged from 632 to 809 $\mu\text{g PNP}$

$\text{g}^{-1}\text{ soil hr}^{-1}$, 649 to 807 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$, 649 to 895 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ and 667 to 947 $\mu\text{g PNP g}^{-1}\text{ soil hr}^{-1}$ at 30 DAI, 60 DAI, 90 DAI and 120 DAI, respectively (Table 8). Application of FYM significantly increased phosphates activity over no application at all observations. It may be due to the fact that FYM provides narrow and optimum C:P ratio which resulted in slow mineralization from organic forms of di-esters and mono-esters (Bedi *et al.* 2009) [2, 3]. Lal *et al.* (1996) [11] found increase in phosphates activity due to application of FYM under incubation in Alfisol of Bihar.

Interaction Effect

The interaction between soil types and FYM application was not significant at all periods of observations.

Conclusion

The biological properties like CO₂ evolution, microbial biomass carbon, microbial count of bacteria, fungi, actinomycetes, dehydrogenase activity, urease activity and phosphates activity increased with the period of incubation irrespective of different soil types, which further enhanced with the application of FYM.

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