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SOIL RESEARCH ON ARECANUT IN THE LAST DECADE

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INTRODUCTION

Arecanut cultivation is mostly confined to high rainfall regions of Kerala, Karnataka, Assam, West Bengal, Tamil Nadu and Maharashtra. Mostly crop is cultivated in gravelly laterite soils of red clay type in southern Kerala and coastal Karnataka (Nambiar, 1949). Laxuriant tree growth is noticed in deep black fertile clay loams soils on the tank irrigated areas. At CPCRI, Regional Station, Vittal the research on effects of continuous use of organic and inorganic sources of fertilizers, nutritional status and requirement in arecanut based cropping models and leaching losses was carried. The results of experiments conducted during last decade are summarized in this article.

Continuous uses of Manures and Fertilizers

A field experiment was conducted to compare the sources of organics and inorganics with and without cultivation during 1969 to 1981. Analyses of soil and leaf samples carried out during 1976-77 showed that the soil was slightly acidified by the applications of inorganic fertilizers. Organic manures increased the organic C content of surface soil. The levels of nutrients, irresspective of treatment differences were medium to high for organic C, total N, available N, P, K and Ca on the surface soil. There was a substantial build up of available nutrients in the soil as a result of additions of manures and fertilizers for 7 years. The leaf nutrients other than N reached the optimum levels. None of the growth attributes and yield of arecanut were significantly affected by the different treatments during the 12 years of the experiment (CPCRI, 1981, 1983).

The microbial count for bacteria, fungi, and actinomycetes was more in the rhizosphere of 0-30 cm depth. The treatment with organic manures alone showed higher microbial population than fertilizers. The counts were more in treatments receiving cultivation (Bopaiah and Bhat, 1981).

Liming in the NPKG experiment

Soil and leaf samples were analysed in September 1982 before lime application from the revised schedule of the NPKG experiment at Vittal. N applications increased exchange acidity up to 3.5 me/100g soil which resulted in considerable base unsaturation both in the surface (0-50 cm) and subsoil (50-100 cm) samples. The arecanut leaf contained sufficient quantities of N, P, K, Ca, Mg, S and accumulated high quantities of Fe, Mn and Al. Applications of lime as $CaCO_3$ at 4 kg/palm in 1983 failed to correct acidity to pH 5.5 in the profile (CPCRI 1985).

Nutritional studies on Yellow Leaf Disease of Arecanut

A plot at Aranthodu (Sulliia Taluk) having the history of yellow leaf disease over 15 years was

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selected and replanted with Mangala cultivar in 1982. Most of the seedlings showed the disease symptoms after a period of 3 years. The level of soil fertility before planting was good.

Arecanut gardens were selected at Aranthodu (Sullia Taluk) and Badagannur (Puttur taluk) during 1983 with a view to superimposing treatments to palms for ameliorating the disease. Pretreatment analyses of leaf, root, and soil were carried out in diseased and apparently healthy palms. The root and leaf samples contained high levels of Fe, Mn and Al. Eight treatments were included, comprising of dolomite, neem cake, Zn and their combinations with NPK and compared with control plants. There was considerable improvement in the health of plants in plots receiving either neem cake, lime or Zn applications. Dolomite addition with Zn reduced the yield of arecanut (CPCRI, 1986).

Areca based Multicropping experiment

Samples collected from the basins and interspaces of arecanut and cacao in 1983 up to 100 cm depth showed that the soil was free from the acid formation. The soils from the inter spaces were low to medium in available P and K. Doubling fertilizer doses in cacao increased the availability of P and K in soil. The organic C contents of surface soils from the basins of arecanut and cacao were satisfactory. The DTPA extractable Fe, Mn, Zn and Cu status of soils was high and required to be reduced to safe levels. The N, P and K contents of cacao leaf appeared to be low. The leaf nutrients contents were optimum in arecanut palms. The arecanut and cacao showed excess of micronutrients in their leaves. The cacao, preferentially absorbed more of Zn and Mn than arecanut (Manikandan *et al.* 1987).

Pretreatment soil samples were collected in July 1983 from arecanut basins and interspaces each at 0-25 cm, 25-50cm and 50-100 cm depths from the existing arecanut based multi cropping experiment at Vittal for fertility evaluation. There was no difference in the nutrient contents of soil amongst the depths of planting. The surface soils from the basin of the palms showed slight acidity (pH 4.9) because of fertilization and were adequate in available N, P and K. The subsoils of the basins as well as the interspaces were lower in fertility.

Soil Fertility in the HDMS plots

The surface soil samples (0-25 cm depth) from 5 micro plots of the existing arecanut based multicropping experiment collected during October 1985 were free from acidity, and adequate in available N, P, K, Ca and Mg (CPCRI, 1986).

Leaf Analysis

Arecanut, pepper, banana, cacao and pineapple leaves were separated into petiole, midrib and lamina and extracted by 0.1 N HCl for estimations of NO_3-N, P and K. Total analyses of the oven dried leaf samples of different crops were carried out for N, P, K, Ca and Mg. In general, NO_3-N and K contents of petiole were higher than midrib and lamina. Extraction with 0.1 N HCl received small fractions of P and K out of their respective total constituents in the leaf. The NO_3^- N, P and K contents of petiole were low as compared to other crop plants. The total analysis revealed low contents of nutrients such as N in pepper, P in banana, P and K in cacao and N, P, Ca and Mg in pineapple leaves.

Nutrients Recycling in Arecanut Garden

Investigations on nutrient additions through rainfall and depletion losses of soil and nutrients in the runoff water of the HDMSC experimental plot were carried out. The June rains added 3 kg N as HN_4^+, 4 kg N as NO_3^-, 7 kg K, 37 kg Ca and 11 kg Mg per ha. The micronutrients, such as Fe, Mn, Zn and Cu were absent in the sample. The arecanut canopy water supplied only 4.5 kg

K and 6.0 kg Ca per ha estimated over the rain water of the corresponding period.

The nutrients present in the leachate of the HDMSC field plot were 10 kg N as NH_4^+, 138 kg N as NO_3^-, 0.25 kg P, 225 kg K, 281 kg Ca and 80 kg Mg per ha. The plot received fertilizers 30 days before sample collection. The nutrients contents of leachate from another plot of arecanut which was not fertilized during monsoon and served as check were 5 kg N as NH_4^+, 93 kg K, 15 kg Ca and 9 kg Mg per ha.

Leaching losses of water soluble nutrients established through soil analysis in the HDMSC plot were 0.10 kg P, 116.06 kg K, 80.83 kg Ca, and 36.83 kg Mg per ha. Similar losses in the NPKG experiment on arecanut were up to the extent of 11.80 kg P, 261.13 kg K, 197.18 kg Ca and 30.68 kg Mg per ha in $N_3P_3K_3G_3$+L (revised schedule, RS); 1.76 kg P, 131.20 kg K, 222.48 kg Ca, 46.02 kg Mg, per ha in $N_2P_2K_2G_2$−L (original schedule, OS); 326.73 kg K, 217.45 kg Ca and 18.40 kg Mg per ha in $N_2P_2K_2G_2$+L (RS); 143.81 kg K, 141.60 kg Ca and 30.68 kg Mg, per ha in the $N_1P_1K_1G_1$−L (RS); 143.81 kg K, 141.60 kg Ca and 30.68 kg Mg, per ha in the $N_1P_1K_1G_1$ −L (OS) and 136.24 kg K, 192.10 kg Ca and 49.59 kg Mg per ha in the $N_1P_1K_1G_1$ +L(RS) recorded in the different treatments.

Studies in losses of soil in the runoff water were carried out on the garden soils in the laboratory, as well as on the leachates from the field. The soil loss decreased with depth from 3-0.6 t/ha. The lechate from the HDMSC plot carried 6t/ha of soil.

Analysis of flood water of the stream Vokethur showed soil loss up to 5t/ha. The nutrients present in the flood water were 1 kg N as NH_4^+, 4 kg N as NO_3^-, 25 kg K, 30 kg Ca and 18 kg Mg per ha.

Nutrients leaching through Nitrification

Column-leaching experiment was started to measure the rate of nitrification of fertilizer-N, release of P and K added to the soil. The nutrients supplied were at 100 ppm each of N, P_2O_5 and K_2O to the soil followed by leaching for 2 months. The leachate was analysed regularly for pH, NH_4^+−N, NO_3^--N, P, K, Ca and Mg. After leaching the columns were sliced at definite lengths the soil dried and analysed for the above constituents.

The nitrification of urea-N was completed by the end of 6th week. The pH of the leachate increased to more than 7 initially, then decreased to 4 due to the formation of nitric acid, followed by a subsequent increase towards neutrality, when the nitrate was drained out of the soil. The column treated with NPK fertilizers showed higher rate of nitrification and acidity of the leachate as compared to N treatment alone. The acidity resulted in the release of 0.06 kg P, 31 kg K, 77 kg Ca and 23.0 kg Mg per ha from the native reserve of the soil.

The dried soil registered the original pH of the sample. The NO_3^--N content was above 10 ppm. The available P level, decreased below 15 cm length of the column (CPCRI, 1986).

N transformations in Garden Soil

Nitrogen mineralisation studies were conducted under laboratory conditions on the surface (0-25 cm) and subsoil (50-100 cm) samples of high density multi species experimental plot (HDMSC), using amonium sulphate (AS), urea, monoammonium phosphate (MAP), diammonium phosphate (DAP) and calcium ammonium nitrate (CAN) as fertilizers. N was added at 10 ppm to the soil. amendments such as $CaCO_3$ (5 mg/g soil) and cattle manure (CM at 1% organaic C, on soil basis) were also added to the fertilizers to study their effects on the nitrification of the applied N. Soil samples after bringing the moisture content to field capacity, were incubated for 8 week period.

The N carriers on the surface soil were completely nitrified during 6 week period. The nitrification of AS on the sub soil was low (36%) as indicated by the accumulation of NH_4^+-N in the exchange complex (40%) (Tables 1 and 2). Liming ($CaCO_3$ at 5 mg/g soil) increased the rate of nitrification (81%) in the subsoil. Lime in general, considerably increased the rate of nitrification of the fertilizer-N from 3-6 week period on the surface soil (Table 3).

All the N sources, increased acidity of the water extract tp pH 4.3. The pH of the 1 N NaCl extract was lower by 0.3 unit than the water extract. Lime additions corrected the soil acidity, generated by N carriers.

Subsequent incubation studies with AS and urea as sources of N added each at 100 ppm N and lime as $CaCo_3$ applied at graded doses (1-5 mg/g soil) showed that exchange acidity could be corrected to pH 5.5 by adding $CaCO_3$ at 1 mg/g soil (2t/ha).

Addition of glucose (C/N = 10) to AS depressed the nitrification (17% N recovered)

Table 1. *Studies on nitrification of AS on the surface soil and subsoil*

Constituents Incubation period in week	Water extract pH		Water extract NH_4^+-N N (ppm)		Water extract NO_3-N N (ppm)		IN NaCl extract pH		IN NaCl extract NH_4^+-N N (ppm)		IN NaCl extract NO3-N N (ppm)	
	0-25	50-100	0-25	50-100	0-25	50-100	0-25	50-100	0-25	50-100	0-25	50-100
1	3.45	3.60	56.00	51.80	Nil	Nil	5.05	3.70	39.20	36.40	Nil	Nil
2	5.40	5.20	46.00	26.60	9.80	1.40	4.40	4.50	32.20	44.80	Nil	Nil
3	4.95	5.10	47.60	33.60	29.40	5.60	4.20	4.20	43.40	57.40	4.20	2.80
4	4.80	4.95	40.60	39.20	54.60	11.20	3.85	4.10	37.80	74.20	5.60	28.00
5	4.20	4.95	23.80	40.60	82.60	9.80	3.90	4.10	22.40	61.60	9.80	1.40
6	4.45	4.60	8.40	35.00	116.20	16.80	3.55	4.05	9.80	56.00	12.60	1.40
7	4.30	4.58	7.00	32.20	113.40	36.40	3.99	4.25	7.00	40.60	14.00	7.00

Table 2. *Nitrification of CAN, MAP and DAP on the surface soil*

Constituents Incubation period in week	Water extract pH			Water extract NH_4^+-N N (ppm)			Water extract NO_3^--N N (ppm)			IN NaCl extract pH			IN NaCl extract NH_4^+-N N (ppm)			IN NaCl extract NO-3-N N (ppm)		
	CAN	MAP	DAP	CAN	MAP	DAP	CAN	MAP	DAP	CAN	MAP	DAP	CAN	MAP	DAP	CAN	MAP	DAP
1	4.90	5.55	5.75	33.60	32.20	32.20	51.80	5.60	5.60	4.25	4.20	4.20	40.60	81.20	88.20	5.60	4.20	4.20
2	5.00	5.65	5.80	33.60	30.80	33.60	50.40	11.20	12.60	4.15	4.15	4.15	37.80	78.40	79.80	11.20	Nil	Nil
3	4.90	5.40	5.60	29.40	43.40	39.20	58.80	28.00	29.40	4.00	4.05	3.95	35.00	64.40	61.60	7.00	7.00	7.00
4	4.48	4.54	4.45	25.20	33.60	25.20	67.20	63.00	78.40	4.38	4.21	4.21	26.60	36.40	25.20	11.20	9.80	14.00
5	4.53	4.43	4.30	16.80	22.40	11.20	85.40	86.80	103.60	4.38	4.07	4.10	16.80	19.60	11.20	12.60	12.60	16.80
6	4.36	4.22	4.22	11.20	9.80	5.60	102.20	113.40	119.00	4.17	3.92	3.95	11.20	9.80	8.40	16.80	19.60	16.80

which could be increased to 59% by lime application. Phosphate at 100 ppm had no effect on the nitrification of AS.

The presence of P was detected on the water extract (0.05 ug/ml), when lime was added ($CaCO_3$ at 5 mg/g soil) which increased the pH to 7.0.

The native organic matter reserve of 20 surface and subsurface soils, nitrified during 4 week and released on an average, 28 ppm N (NO_3^--N) for every 1 per cent organic C (Walkley Black). Lime addition increased the recovery to 42 ppm and 19 ppm N respectively for surface and subsurface soils.

Nitrification of urea, at 100 ppm N, under high moisture regime (1:1 soil : water ratio after attaining field capacity) was enhanced to 3 week period (Table 4). The fertilizer N also generated

Table 3. *Effect of liming, on the nitrification of AS on the surface and subsoil*

Constituents	Water extract						IN NaCl extract					
Incubation period	pH		NH_4-N N (ppm)		NO_3-N N (ppm)		pH		NH_4-N N (ppm)		NH3-N N (ppm)	
in week	0-25	50-100	0-25	50-100	0-25	50-100	0-25	50-100	0-25	50-100	0-25	50-100
1	7.50	7.45	44.80	39.20	7.00	7.00	7.60	7.30	43.40	53.20	Nil	5.60
2	7.50	7.84	32.20	32.20	26.60	15.40	7.25	7.50	32.20	37.80	5.60	5.60
3	7.15	7.47	8.40	11.20	95.20	65.80	7.00	7.50	21.00	18.20	11.20	11.20
4	7.05	7.50	4.20	5.60	93.80	75.60	7.00	7.54	4.20	12.60	1.40	8.40
5	-	7.45	-	4.20	-	81.20	-	7.39	-	4.20	-	9.80

Table 4. *Effect of high moisture regime, on the nitrification of Urea-N, alone, and in combination with lime and cattle manure.*

Constituents	Water extract								
Incubation period	pH			NH_4^+-N N (ppm)			NO_3^--N N (ppm)		
in week	N	N+L	N+CM	N	N+L	N+CM	N	N+L	N+CM
1	5.40	6.55	6.51	28.00	18.20	28.00	43.40	60.20	46.20
2	4.70	6.14	6.04	16.80	5.60	9.80	88.20	109.20	86.80
3	4.50	5.68	6.07	7.00	5.60	5.60	110.60	109.20	85.40

Constituents	IN NaCl extract								
Incubation period	pH			NH_4^+-N N (ppm)			NO_3^--N N (ppm)		
in week	N	N+L	N+CM	N	N+L	N+CM	N	N+L	N+CM
1	4.39	4.79	5.05	33.60	23.80	25.20	7.00	7.00	4.20
2	4.36	5.30	4.88	19.60	9.80	11.20	14.00	18.20	15.40
3	4.26	4.78	4.91	8.40	7.00	8.40	15.40	14.00	11.20

acidity under submerged conditions, which was corrected by addition of lime (1 mg/g soil) and cattle manure (1% OC).

The cattle manure, under water logging released water soluble P (3.9 ppm) and K (110.2 ppm) during the course of nitrification. The water soluble K contents of soils of remaining treatments were 24.2 ppm, 18.8 ppm and 13.4 ppm for soil + urea, soil + urea + lime and soil alone (control) respectively. The water soluble Ca extracted was 85.5 ppm, 60.8 ppm, 116.8 ppm and 16.1 ppm for treatments viz., soil + urea, soil + urea + CM, soil + urea + L and soil alone (control) respectively. The Mg in the water extract was 30.3 ppm, 25.1 ppm, 25.1 ppm and 11.5 ppm respectively in soil + urea, soil + urea + CM, soil + urea + L and soil alone (control) treatments. The Fe^{2+} content of soil water treated with urea-N was 3 ppm.

Soil columns of 1 m length were erected, after filling in the polyethylene tubing of 4cm diameter with surface and subsoil samples. Urea-N was added at 100 ppm N, either in the presence of lime ($CaCO_3$ at 1 mg/g soil) or CM (1% OC on soil basis). After one week of incubation, the columns were leached with water at weekly intervals and the leachate was analysed for NH_4-N and NO_3^--N. Nitrification was completed during 5 week period. Organic matter depressed the rate of nitrification of the fertilizer-N. Equal amount of lime and CM increased the pH of the leachate from 6.2 to 6.5.

The columns were segmented at 0-25 cm, 25-50 cm and 50-100 cm depths and dried soil samples were analysed. The data revealed the NO_3^--N accumulation at 50-100 cm depth, resulting in the decrease of pH to 3.5 even in the lime treatment ($CaCO_3$ 1 mg/g soil). Immobilised N in the presence of CM was recovered as water soluble NO_3^--N (35.16%), exchangeable NH_4^+-N (12%) and NO_3^--N (41.10%) forms (Table 5). Cattle manure alone (1% OC) added to the soil column released 167 mg N out of which 46.1%, 34.8% and 19.1% were water soluble NO_3^--N exchangeable NH_4^+-N and NO_3-N respectively. The N released, corresponds to 52.32 ppm N in the soil. Lime treatment nitrified the fertilizer N faster than CM contributing to 70.35 per cent, 23.45 per cent and 10.85 per cent respectively of water soluble NO_3^--N exchangeable NH_4^+-N and NO_3-N fractions (CPCRI, 1986).

A Neubauer seedling test with rice plant conducted on the untreated soil (0-25 cm depth) sample of HDMSC experimental plot extracted through plant growth, 57 ppm N, 10 ppm P, 104 ppm K, 25 ppm Ca, 12 ppm Mg, 0.5 ppm Fe and 0.9 ppm Al. In the subsoil, these values were 48 ppm N, 11 ppm P, 99 ppm K, 31 ppm Ca, 12 ppm Mg, 0.4 ppm Fe and 0.9 ppm Al. N recovered through plant growth was 56 per cent for the surface soil and 37 per cent for the sub soil of the fertilizer N applied at 100 ppm N as urea. The recovery of applied P and K (added at 100 ppm each of P_2O_5 and K_2O) was more in the treatment of CM (1% OC). Lime ($CaCO_3$ at 1 mg/g soil) had no effect in increasing the P availability to the test plants.

P Transformations in Garden Soil

Phosphorus retention studies were undertaken under laboratory conditions using surface (0-15 cm) and subsoil (85-130 cm) samples of a virgin lateritic soil profile. P was added at incremental rate, alone and in different combinations with N as AS, CM, gypsum (G) and lime (L) as $CaCO_3$; and incubated for various lengths of time at variable moisture regimes of field capacity (40% water), saturated condition (1:1 soil : water ratio, after attained field capacity) and water logged conditions (1:10 soil : water ratio, after attained field capacity). After adding P to the soil, it was immediately steam-dried for 30 min and extracted. P-treated incubated soil was extracted with water. NH_4F (0.03 N) with differing

Table 5. *Analysis of air-dried soil samples from columns to study the nitrification of urea-N, in the presence of lime and cattle manure.*

Constituent	Soil suspension pH (H_2O)			Water extract pH			1 N NaCl extract pH			Water extract NO_3^--N N (ppm)			1 N NaCl extract NH_4^+-N N (ppm)			NO_3^--N N (ppm)		
Treatment	0-25	25-50	50-100	0-25	25-50	50-100	0-25	25-50	50-100	0-25	25-50	50-100	0-25	25-50	50-100	0-25	25-50	50-100
N+L	5.10	3.55	3.85	6.45	4.52	4.60	4.90	4.39	4.42	50.40	65.80	82.60	14.00	12.60	33.60	8.40	12.60	11.20
										(37.80)	(49.35)	(123.90)	(10.50)	(9.45)	(50.45)	(6.30)	(9.45)	(16.80)
N+CM	5.95	5.55	4.40	6.40	6.56	4.85	5.16	5.42	4.47	22.40	32.20	82.60	18.20	18.20	42.00	47.60	44.80	56.00
										(16.80)	(24.15)	(123.90)	(13.65)	(13.65)	(63.00)	(35.70)	(33.60)	(84.00)
CM	5.23	5.90	4.35	6.55	6.55	5.15	5.34	5.69	4.51	19.60	12.60	19.60	26.60	15.40	15.40	9.80	9.80	10.20
										(14.70)	(9.45)	(29.40)	(19.95)	(11.55)	(23.10)	(7.35)	(7.35)	(15.30)

strengths of HCl was also employed for P extraction. The P released, through these extractants was measured.

The physico-chemical properties of the soil used in the investigation were estimated. The subsoil contained 20 per cent more clay than the surface soil. The top soil was sandy but high in organic matter. The sequioxides content of the subsoil was more than the surface soil. The total P content of the surface soil was higher than its subsoil and the difference of 75 ppm was due to organic matter. The pH of the soil samples of both the depths was around 5.30. The soil contained traces of Bray P-1 extractable P.

A series of incubation experiments and also a Neubauer seedling culture were conducted under laboratory and green-house conditions. The P from 100-1000 ppm was added to 3 sets of surface soil. The first set was extracted with water after 24 h of incubation. The second set was immediately steam-dried and extracted with water. The third set was stored for 3 week under field capacity. The soil was first extracted with water and then with 0.03N NH_4F. The recovery of P increased with the increase in the concentration of added P to the soil. The availability of water soluble P was in the order : 24 h incubation > steam-drying >3 week incubation. The F^- extracted more P than water. The percentage recovery of P in all the 3 sets was within a narrow limit. In general P increased the pH of the soil. The pH of the soil, due to the different levels of P additions, was not different in any of these sets of the experiment (Table 6).

P retention studies were conducted in the subsoil. The soil was treated with P, as KH_2PO_4 (100-5000 ppm) and incubated for 24 h. Another set was taken for steam-drying, followed by P extraction. P was extracted by water and Bray P-1 reagent after 24 h incubation. In the case of steam-drying, it was extracted by water alone. The Bray P-1 extracted more P than water. The steamdrying, recorded the least amount of water soluble P. The subsoil retained more amounts of added P to the soil as evidenced by the lower percentages of recovery. The increase in pH, registered due to P additions was less in the subsoil.

Table 6. *P availability on the surface soil, as affected by two different periods of incubation, steam-steam-drying and F^-*

		After 24h incubation			After steam-drying			After 3 week incubation				
								0.03N NH_4F in water Water extract				
		Water extract			Water extract							
Sl. No.	P added (ppm)	pH	P reco vered (ppm)	P reco-vered %	pH	P reco-vered (ppm)	P reco-vered %	pH	P reco-vered (ppm)	P reco-vered %	P reco-vered (ppm)	P reco vered %
1	100	7.55	6.00	6.00	7.40	3.60	3.60	7.35	1.40	1.40	9.50	9.50
2	200	7.55	14.40	7.20	7.50	9.20	4.60	7.44	3.80	1.90	19.75	9.87
3	300	7.55	28.00	9.33	7.55	14.80	4.93	7.40	5.20	1.73	34.00	11.33
4	400	7.55	35.50	8.87	7.55	23.00	5.75	7.50	7.50	1.90	54.00	13.50
5	500	7.53	55.00	11.00	7.55	30.00	6.00	7.35	13.00	2.60	70.00	70.00
6	600	7.58	55.00	9.16	7.55	44.00	7.33	7.35	15.00	2.50	82.00	13.66
7	700	7.55	81.00	11.57	7.50	52.00	7.43	7.45	19.50	2.80	115.00	16.43
8	800	7.52	94.00	11.75	7.55	67.00	8.37	7.45	21.00	2.62	130.00	16.25
9	900	7.52	120.00	13.33	7.50	75.00	8.33	7.40	26.00	2.90	145.00	16.11
10	1000	7.50	120.00	12.00	7.55	94.00	9.40	7.45	30.00	3.00	195.00	19.50

A Sample of subsoil was supplied with 1000 ppm P as KH_2PO_4 and incubated for 5 week period. The soil treated P was analysed for its water soluble P contents at weekly interval. The water soluble P recovered was 33.0 ppm, 23.0 ppm, 19.5 ppm, 17.0 ppm and 17.0 ppm for corresponding incubation periods of 1, 2, 3, 4 and 5 weeks respectively. The water soluble P content gradually decreased up to 4 week and thereafter did not change.

A set of 8 subsoil samples was treated each with 500 ppm P and incubated for 24 h at field capacity. Later these were extracted with HCl (1N to 10^{-7} N) from pH 1 to 7.0 in the presence of 0.03N NH_4F. The F primarily extracted P from the soil. The acidity had no appreciable effect on P availability in the pH range of 1-7. The 1N HCl, extracted more P than F, which is often rated as the measure of mineral P in the soil. The native soil contained 3.6 ppm P extracted by this reagent.

The surface soil was treated with 1000 ppm P in the presence of N (100 ppm N as AS), L ($CaCO_3$ at 1 mg/g soil), N+L CM (1% OC on soil basis), N+CM, G ($CaSO_4$ at 1 mg/g soil) and N+G at varying moisture regimes of field capacity (FC) saturated conditions (SC) and water logged conditions (WLC) and incubaeted for 4 week period. The P on the water extract was measured. The P availability in the soil was increased by L and CM and reduced by N and by additions. The higher content of P released by CM was due to its high P content. The availability of P in general was slightly more than WLC. High moisture regime had no effect on the pH was increased from 5.35 to neutrality as a result of incubation. There was however a slight increase in the pH of the native soil affected by the increased levels of moisture. Another set of experiment with slight modifications was conducted as above using the subsoil with similar results. The CM after 4 week of incubation alone extracted substantial quantity of water soluble P (320 ppm).

P availability was measured in the presence of increasing levels of L and G separately on the surface and subsoil samples under different moisture regimes. Lime as $CaCO_3$ and G each was added from 2-5 mg/g soil and incubated with 1000 ppm P for 4 weeks time. The P released in Water was estimated. Increased L and G levels reduced the content of water-soluble P in the soil. However, the rate of reduction was more due to G than L applications. Waterlogging enhanced the content of P extracted by water. The pH of soil was increased by L and lowered by G.

A Neubauer seedling culture experiment was set up on surface virgin lateritic soil. P as single superphosphate (SSP), was added from 50 to 1000 ppm with one control plot consisting of 12 treatments. N and K each at 100 ppm was added as AS and KCl respectively to individual treatments. Every pot was sown with 100 ragi (*Eleusine coracana* L.) seeds and watered to field capacity. The seedlings were harvested 25 days after germination. The above ground dry matter contents of plants were not different beyond 300 ppm P supplied. There was an apparent increase in the P content of tissue at higher P levels. The total P uptake was similar to that of percentage P content. The higher P content of tissue (0.2%) at 100 ppm P or above may be desirable in the P nutrition of crop plants. The control plants exhibited stunted growth and recorded low dry matter content. The P content of tissue was also low.

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