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R Thamaraiselvi
Department of Soil Science and Agricultural Chemistry Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli Tamil Nadu Agricultural University, Tamil Nadu, India

K Arulmozhiselvan
Professor and Project Director, Department of Soil Science and Agricultural Chemistry Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli Tamil Nadu Agricultural University, Tamil Nadu, India

Precipitation of soluble forms of fertilizer phosphorus in saline irrigation water

R Thamaraiselvi and K Arulmozhiselvan

Abstract
Phosphorus (P) is a major nutrient required for plants particularly for the root growth, nucleoprotein synthesis and energy transfer. It does not exist as soluble forms abundantly in soil. Different forms applied P supplied through fertilizers are not fully absorbed by the plant, because substantial amount of P is precipitated in soil immediately after application and irrigation. The precipitated P exists in fixed forms and may dissolve and become available in the next season to some extent, which is known as residual effect. Precipitation of P occurs mainly due to interaction of soluble P with metal ions that are present in soil and also in irrigation water. In this study P precipitation of different P forms with different saline irrigation water was estimated. Precipitation of P recorded was high in saline water and per cent P precipitated decreased with P fertilizers in the order: Single Super Phosphate (6.49 mg P L^{-1}), Diammonium Phosphate (5.65 mg P L^{-1}), Monoammonium Phosphate (2.47 mg P L^{-1}), All-19 (2.44 mg P L^{-1}) and Potassium dihydrogen Phosphate (2.26 mg P L^{-1}). Precipitation of P was moderate in medium saline water and low in non-saline water. By scaling up to a practical range it was calculated that with the irrigation at 5 cm depth of water, surface application of 40 kg P ha^{-1} (91.6 kg P_2O_5 ha^{-1}) would cause fertilizer P to become insoluble to the tune of 34.4 kg P ha^{-1} (78.7 kg P_2O_5 ha^{-1}) if SSP is applied, 27.0 kg ha^{-1} (61.8 kg P_2O_5 ha^{-1}) if DAP is applied, 19.7 kg ha^{-1} (45.1 kg P_2O_5 ha^{-1}) if MAP is applied and 16.1 kg ha^{-1} (36.8 kg P_2O_5 ha^{-1}) if All-19 is applied.

Keywords: Saline water irrigation, precipitation of P, water soluble P, P fertilizers, interaction P with metal ions

Introduction
Plants consume phosphorus (P) importantly for root development and energy supply. Besides in plants P is a structural compound in gene, chromosome, phospholipids, phosphoproteins and many coenzymes. Commonly P does not occur as abundantly in soil as nitrogen and potassium. The concentration of total P in soil surface ranges from 0.02 to 0.10 per cent and it is absorbed by plants largely as orthophosphate ions ($H_2PO_4^-$ and HPO_4^{2-}), which are present in soil solution. Phosphatic fertilizers contain various forms of P. Soluble P readily reacts with metallic ions and gets precipitated as insoluble metallic phosphates. Saline irrigation water contains substantial soluble salts of calcium, magnesium and other divalent metallic ions which can precipitate soluble P (Syers *et al.*, 2008) [13]. The solubility of precipitated P forms in soil solution mainly depends on soil pH (Tisdale *et al.*, 2016) [14].

Conversely P solubility in sodic soil is very high because the sodic soils have high sodium ion concentration and it will form water soluble sodium phosphate. However, in salt affected soils having sodicity and salinity nutrient uptake is hampered, causing nutrient deficiency in plants. The low nutrient supply in sodic soil is due to the lack of water and oxygen supply to the plant root in dispersed clay condition (Naidu *et al.,* 1993) [10].

When applying the phosphatic fertilizer in one season, it may not be fully utilized by crops due to P fixation. Some amount of P fixed from fertilizer may be released in next season. This phenomenon known as residual effect of fertilizers has more consideration while fertilizing crops. Residual effect was mostly noted in soils with high capacity to adsorb phosphate and with plants particularly having proliferated root system with high root density and distribution (Barley, 1970) [1]. Residual effect is not only by slow reaction of phosphate fertilizer in soil but also due to a portion of applied P removed by first crop. Therefore, current availability of the previously applied phosphatic fertilizer does not have unique value throughout the season in subsequent crop (Barrow *et al.*, 1972) [2]. Fixation of P was first recognized in Europe around 1850 and it was reported that the soil had an ability to retain the P in it. The insoluble P

Correspondence
K Arulmozhiselvan
Professor and Project Director, Department of Soil Science and Agricultural Chemistry Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli Tamil Nadu Agricultural University, Tamil Nadu, India

compounds present in soils can be classed generally as the oxy- and hydroxyl- phosphates of Fe^{3+}, Fe^{2+}, Al^{3+}, Ca^{2+}, Mg^{2+} and Mn^{2+}. These metal ions provide the more sorption sites for P (Hemwall, 1957) [4]. This will leads to increasing P fixation particularly in calcareous soil. Zinc in a soil or within plant has antagonism with P which is known as negative interaction between P and Zn (Mousavi, 2011) [8].

When fertilizer P reacts in calcareous soil, it is converted into dicalcium phosphate dihydrate or octacalcium phosphate and some case it may eventually converted into hydroxy apatite, which are all slow releasing forms of P fertilizers (Leytem and Mikkelsen 2005) [5]. Application of single super phosphate (SSP) to a soil will lead to dissolution of mono calcium phosphate and result in the formation of slowly soluble dicalcium phosphate and phosphoric acid. This phosphoric acid will subsequently dissociate to form dihydrogen phosphate and hydrogen ion which reduce the pH < 2.0 and soil will become strongly acidic. In that state P is precipitated with Fe and Al compounds in soil (Selim, 2018) [12]. Prevalence of micronutrient deficiency is mainly by excessive application of P in cultivated soil. Majority of P and micronutrient interactions include P-Zn, P-Fe, P-Cu, P-Mn, P-Mo and P-B. This is called P- induced micronutrient deficiency and the most common interaction occurs with Zn, Fe and Cu (Murphy et al., 1981) [9]. Saline irrigation water is a carrier of most of the neutral soluble metallic salts. Hence, prior to fixation of P in soil considerable fraction of fertilizer P is precipitated in irrigation water itself. The extent of precipitation of P increases with salinity of irrigation water. In order to account for amount of precipitation of P the present study was undertaken taking different forms of P fertilizers viz., monocalcium phosphate (SSP), ammonium phosphates (MAP, DAP) and combined forms and reacting with irrigation water having variable salinity.

Materials and methods

For recording the amount of P precipitated in irrigation water and in soil solution laboratory experiments were conducted. For the purpose 3 irrigation water samples varying in salinity were collected within the campus of Anbil Dharmalingam Agricultural College and Research Institute, TNAU, Trichy.

For each P fertilizer source one laboratory experiment was organized with a batch of containers for 16 concentrations of P in two replications. In each polythene container (200 ml) a known volume of irrigation water sample (100 ml) was taken (in 16 polythene containers), in which 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 ml of 1000 µg P ml^{-1} solution was supplied from different P sources viz., potassium dihydrogen phosphate (KH_2PO_4), diammonium phosphate (DAP), single super phosphate (SSP), All-19 (19:19:19), mono ammonium phosphate (MAP). After the addition of soluble P, the containers were kept for overnight at room temperature for incubation to allow soluble P to get precipitated with metal ions that were naturally present in irrigation water like Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+} and Zn^{2+}.

Analysis of water soluble P

After the overnight incubation period, solution in each container was estimated for soluble P concentration by vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973). For the estimation solution in the container was filtered through Whatman No. 3 filter paper and then filtrate was collected in a separate vial. Then 2 ml of filtrate was pipetted out into 25 ml volumetric flask, in which 10 ml of colour reagent was added for colour development. Finally the volume was made up to 25 ml with distilled water. Then the content of volumetric flask was mixed thoroughly and allowed to stand for 30 minutes for yellow colour development. The coloured solution was estimated for P concentration in spectrophotometer at 420 nm.

Estimation of soluble P in irrigation water (Recovered P [RP])

After incubation (overnight) and precipitation reaction the soluble P present in irrigation water was calculated by the following formula:

$$\text{Soluble P (mg L}^{-1}) = \frac{\text{Concentration of P in coloured solution (mg ml}^{-1}) \times \text{Volume of volumetric flask (ml)}}{\text{Aliquot of irrigation water (ml)}} \times 1000$$

Computation of Precipitated P [PP] in irrigation water (%)

Phosphorus precipitated in percentage was calculated by the following formula:

$$\text{P precipitated (\%)} = \frac{[\text{P added (mg L}^{-1}) - \text{P recovered (mg L}^{-1})]}{\text{P added (mg L}^{-1})} \times 100$$

Analysis of irrigation water

Water samples collected were subjected to preliminary analysis. Determination for soil reaction (pH) by potentiometry and electrical conductivity by conductometry was done (Jackson, 1973). Metallic ions viz., Fe, Zn, Mn, Cu were estimated in atomic absorption spectrometry (Piper, 1966). Phosphorus was estimated by vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973). Sodium and potassium were estimated by flame photometry (Piper, 1966). Calcium and magnesium were estimated by versenate method (Jackson, 1973). Carbonate and bicarbonate were estimated by titrimetry (Piper, 1966). Sulphate was determined by Turbidimetry (Jackson, 1973). The chloride was estimated by Mohr's method (Jackson, 1973).

Analysis of phosphatic fertilizers

Fertilizers taken up for the study were analysed for water soluble P content by vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973). One gram of finely ground P fertilizer was dissolved in 150 ml of distilled water and volume was made up to 250 ml. From this stock solution 5 ml was pipetted out into 25 ml of volumetric flask and for colour development 5 ml of colour reagent was added and volume was made up to 25 ml. After 30 minutes, absorbance was recorded in spectrophotometer at 420 nm.

Results and discussion
Characteristics of irrigation water

For the study 3 quality of irrigation water samples varying in salinity were taken. On quality analysis (Table 1) EC was 0.96 dS m^{-1} in non-saline water, 2.89 dS m^{-1} in moderately saline water and 4.81 dS m^{-1} in saline water, wherein Na$^+$ concentration was 5.55, 20.27 and 26.07 m.e L^{-1} and correspondingly Cl$^-$ concentration was 4.80, 19.50 and 31.40 m.e L^{-1} respectively. The pH of the water samples varied slightly between 7.42 and 7.82. Based on P analysis in incubated irrigation water the results were computed and expressed as P recovered (RP) in solution as soluble P (mg P L^{-1}) and precipitated P (PP) as insoluble P (%).

Precipitation of P in non-saline water

With non-saline irrigation water (Table 2) increased addition

of fertilizer P resulted in increase in concentration of RP. Irrespective of different P sources the added P was almost fully recovered in solution, recording 133.2 to 147.9 mg L^{-1} with the addition of the highest concentration (150 mg L^{-1}) of fertilizer P. At this level, the greatest precipitation occurred in SSP (16.8 mg L^{-1}), whereas the other fertilizers rendered very little quantity of soluble P for precipitation, which ranged from 2.1 to 5.1 mg L^{-1}. With the addition of soluble P in increasing concentration correspondingly caused precipitation of P in the decreasing order in non-saline water. The extent of precipitation occurred was high with DAP (44.7 to 47.0 %) within 10 to 30 mg L^{-1} of added P, which was followed by SSP (36.0 to 40.5 %) within 20 to 50 mg L^{-1} of added P. With respect to water soluble fertilizers the extent of PP was low. Addition of MAP at 10 to 20 mg L^{-1} caused PP to range from 17.5 to 18.0 per cent, while All-19 at 10 to 40 mg L^{-1} caused PP to range from 14.3 to 16.8 per cent. The standard source of soluble P in the form of KH_2PO_4 was also precipitated P to high extent (38.3 to 39.0 %) as that of DAP and SSP.

Precipitation of P in moderately saline water
Moderately saline irrigation water (Table 3) precipitated more of P than non-saline and saline irrigation water. From various P fertilizer sources, addition of soluble P in increasing concentration increased the extent of precipitation also proportionately. At the level of 10 to 40 mg L^{-1} of P, SSP addition caused the high PP (54.0 to 50.8), which was followed by DAP (53.0 to 51.7 %) within 10 to 30 mg L^{-1} of added P. Addition of MAP at 10 to 20 mg L^{-1} caused PP to range from 52.0 to 51.5 per cent, while All-19 at 10 mg L^{-1} caused PP to account for 50.0 per cent. The standard source of soluble P in the form of KH_2PO_4 was also precipitated P to high extent (35.0 %) as that of DAP and SSP.

Precipitation of P in saline water
More of P was precipitated in saline irrigation water (Table 4) than non-saline irrigation water. With increasing addition of soluble P from various P fertilizer sources, the extent of precipitation also proportionately increased. The extent of precipitation occurred was high with SSP (90.0 to 98.0 %) within 10 to 30 mg L^{-1} of added P, which was followed by DAP (77.2 to 81.0 %) within 10 to 50 mg L^{-1} of added P. Addition of MAP at 10 mg L^{-1} caused PP to account for 74.0 per cent while All-19 at 10 mg L^{-1} caused PP to account for 73.0 per cent. Addition of KH_2PO_4 also precipitated P to high extent (73.0 %) as that of DAP and SSP.

Effect of salinity on fraction of P precipitated
Variable pattern of % precipitation of P was observed in non-saline, moderately saline and saline water (Figure 1 to 5) for the different sources of P. Potassium dihydrogen phosphate (KH_2PO_4) was taken as a pure form of standard chemical representing soluble P. In non-saline irrigation water only low range of % precipitation was noticed for KH_2PO_4 which also uniformly decreased with increase in added P. In moderately saline irrigation water the % precipitation initially increased with increase in concentration up to 30 mg L^{-1} and then slowly decreased in a moderate range up to 90 mg L^{-1}, thereafter only least proportion of % precipitation was found. When KH_2PO_4 was added to saline irrigation water the highest range of % precipitation of P occurred. Low amount of P addition enhanced the highest % precipitation and further increase in P addition steeply and almost uniformly decreased % precipitation of P. The results showed that % precipitation

of added P was in general highest in saline water, moderate in moderately saline water and least in non-saline water.
Highly variable % precipitation pattern in irrigation water of variable salinity was noticed for the most conventionally used fertilizer SSP. In saline water almost all soluble P in SSP was precipitated at low added P concentration of 20 mg L^{-1} thereafter the % precipitation decreased linearly reaching about 40 per cent precipitation at the highest added level of 150 mg L^{-1}.
In moderately saline water also there was a linear decrease in % precipitation of P with SSP which ranged from about 55 to 25 per cent. However, in non-saline water % precipitation of P increased with increased addition of P up to 40 mg L^{-1} and further increase in added P decreased slowly % precipitation, which finally reached about to 10 per cent at 150 mg L^{-1}.
Solubilising P in the form of DAP indicated almost constant % precipitation up to 50 mg L^{-1} in saline and moderately saline water, while it was up to 30 mg L^{-1} in non-saline water. However, % precipitation thereafter decreased linearly. Overall, greater precipitation occurred in saline water than moderately saline water, whereas in non-saline water % precipitation was very low. In contrast, addition of water soluble P fertilizers to non-saline water caused moderate % precipitation of P initially which was rapidly slowed down with subsequent addition of P in increasing proportion.
The trendy lines distinctly found with All-19, clearly indicated precipitation of P highly in saline water, moderately in moderately saline water and slowly in non-saline water. In MAP considerably high and almost similar % precipitation happened in both moderately saline and saline water. In non-saline water % precipitation was very much less. Saline irrigation water always has reactive cation and anion species. Since cations always have very high affinity for ionic P species readily react with most of the added P and precipitate. In the present study the results have really indicated that the extent of precipitation varied accountably, which were different for different form of P and different range of salinity.

Interaction of P with cationic species
In general, irrespective of P forms there was increased % precipitation while adding P at low concentration. This might be due to more chances for the cations present in irrigation water to interact with little amount of soluble P added. Earlier studies with solubility of P compounds showed that dilution also caused the increased P precipitation rate (Lindsay et al., 1962) [7]. The extent of precipitation of P was high in saline water when compared to non-saline water. Possibly the abundant presence of divalent calcium and magnesium estimated in the saline water would have caused precipitation of P as relatively insoluble calcium phosphate and magnesium phosphate respectively. Leytem and Mikkelsen (2005) [6] indicated that calcium ion has more affinity towards P precipitation and application of P fertilizers in soil with abundant calcium ions caused conversion of fast soluble monocalcium phosphate into slowly soluble dicalcium phosphate or octacalcium phosphate.
Estimated amount of insoluble P in the present study in irrigation water may have straight relationship with the soluble salts or otherwise the metallic cations present in water viz., Ca^{2+}, Mg^{2+}, K^+, Na^+, Fe^{2+}, Fe^{3+}, Al^{3+}, Zn^{2+}, Cu^{2+}, etc. The phosphate compounds of trivalent cations may be strongly insoluble, divalent cations may be sparingly soluble, while monovalent cations may be weakly ionizing. The shape of precipitation lines obtained in the present study may be

indicative of the order of reaction with metallic ions. Preferably trivalent/ divalent metallic phosphate could have formed initially when P fertilizers were added at low concentration in irrigation water. Horizontal lines in the plot might be indicative of such sort of formation of compounds. When trivalent metallic ions have fully reacted, further addition of soluble P might have reacted with monovalent cations forming intermediately soluble P compounds, which would have slowed down the precipitation. This phenomenon would have caused the downward sloping of line, as every increased addition was limiting further precipitation due to want of reacting cationic species.

Effect of forms of P fertilizer on P availability
On large scale interpretation it could be identified that saline water can render substantial amount of soluble fertilizer P to insoluble compounds, when irrigating the field profusely after fertilizing P on soil surface. For instance, irrigating up to 5 cm depth of water can leave 0.5 million litres of water in a hectare, and surface application of 40 kg P ha^{-1} (91.6 kg ha^{-1} P_2O_5) would cause a soluble P concentration of 80 mg L^{-1}. With saline irrigation water (EC> 4 dS m^{-1}) was allowed in field after P application (at 40 kg P ha^{-1}) and leaving overnight it is expected that fertilizer P would become insoluble to the tune of 34.4 kg ha^{-1} (78.7 P_2O_5 ha^{-1}) if SSP is applied, 27.0 kg ha^{-1} (61.8 P_2O_5 ha^{-1}) if DAP is applied, 19.7 kg ha^{-1} (45.1 P_2O_5 ha^{-1}) if MAP is applied and 16.1 kg ha^{-1} (36.8 P_2O_5 ha^{-1}) if All-19 is applied.

Therefore in P fertilization salinity of water used for irrigation has direct impact on availability of P in soil as well as absorption of P by plants. In an earlier study a conclusion was made not to recommend application of P, when using irrigation water which has high concentration of calcium and magnesium under trickle irrigation, because this may lead to the formation of dicalcium phosphate and dimagnesium phosphate, and cause blockage in irrigation pipes and emitters (Bester *et al.,* 1974; Rolston *et al.,* 1979) [3, 11].

Conclusion
On the basis of results the fertilizers evaluated for the susceptibility of getting precipitated on reaction with metallic ions of irrigation water decreased in the order: SSP>DAP>MAP>All-19. Interpretations and findings emanated from the study may have a practical significance for applying entire dose of P fertilizer as basal dressing, with respect to P availability when using saline irrigation water. There is also a need to device new methods of inhibiting the chemical interaction of the soluble P forms with cations of irrigation water. It may imply that with saline water irrigation split application of fertilizer P may increase P use efficiency.

Table 1: Chemical characteristics of irrigation water

Characteristics	Unit	Quality of irrigation water		
		Non-saline	Moderately saline	Saline
Chemical reactivity, pH	pH	7.98	7.82	7.42
Electrical Conductivity, EC	dS m^{-1}	0.96	2.89	4.81
Water soluble Cations and Anions				
Potassium, K$^+$	m.e. L^{-1}	0	0.091	0.072
Sodium, Na$^+$	m.e. L^{-1}	5.55	20.27	26.07
Calcium, Ca^{2+}	m.e. L^{-1}	0.4	0.5	3.4
Magnesium, Mg^{2+}	m.e. L^{-1}	2.72	5.7	8.5
Ferrous, Fe^{2+}	mg L^{-1}	0.077	0.114	0.118
Zinc, Zn^{2+}	mg L^{-1}	0.021	0.023	0.034
Manganese, Mn^{2+}	mg L^{-1}	0	0	0
Copper, Cu^{2+}	mg L^{-1}	0.008	0.012	0.012
Carbonate, CO$_3^{2-}$	m.e. L^{-1}	0	1.7	1.1
Bicarbonate, HCO$_3^-$	m.e. L^{-1}	7.2	11.8	14
Sulphate, SO$_4^{2-}$	m.e. L^{-1}	0.46	1.81	2.59
Chloride, Cl$^-$	m.e. L^{-1}	4.8	19.53	31.44

Table 2. Effect of non-saline water on precipitation of P in phosphatic fertilizers

Added P	Sources of fertilizer phosphorus									
	KH$_2$PO$_4$		SSP		DAP		All-19		MAP	
(mg L^{-1})	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)
10	8.1	19.0	6.9	31.0	5.3	47.0	8.4	16.0	8.2	18.0
20	12.2	39.0	12.8	36.0	10.7	46.5	17.0	15.0	16.5	17.5
30	18.5	38.3	18.7	37.7	16.6	44.7	25.7	14.3	25.5	15.0
40	29.2	27.0	23.8	40.5	25.0	37.5	33.3	16.8	34.6	13.5
50	35.9	28.2	32.0	36.0	34.6	30.8	42.8	14.4	44.5	11.0
60	43.3	27.8	39.6	34.0	47.7	20.5	52.6	12.3	53.1	11.5
70	51.8	26.0	47.4	32.3	58.0	17.1	62.4	10.9	62.0	11.4
80	61.5	23.1	55.7	30.4	69.6	13.0	72.6	9.3	71.6	10.5
90	78.2	13.1	67.4	25.1	82.1	8.8	83.7	7.0	80.9	10.1
100	90.9	9.1	77.8	22.2	93.6	6.4	96.0	4.0	91.0	9.0
110	105.0	4.5	88.1	19.9	105.1	4.5	105.8	3.8	101.2	8.0
120	115.9	3.4	100.9	15.9	115.9	3.4	117.0	2.5	111.5	7.1
130	126.3	2.8	111.8	14.0	126.9	2.4	127.0	2.3	122.3	5.9
140	136.8	2.3	122.5	12.5	137.0	2.1	137.6	1.7	133.1	4.9
150	147.2	1.9	133.2	11.2	146.6	2.3	147.9	1.4	144.9	3.4
SEd	5.92	-	4.95	-	5.47	-	3.77	-	4.22	-
CD	12.09**	-	10.01**	-	11.17**	-	7.70**	-	8.62**	-

SEd – Standard Error of mean difference;
CD expressed at P=0.05; Significance noted at 5% (*) and 1% (**) levels
RP- Recovered P (water soluble P in solution); PP-Precipitated P (insoluble P suspended in solution)

Table 3. Effect of moderately saline water on precipitation of P in phosphatic fertilizers

| Added P | Sources of fertilizer phosphorus | | | | | | | | | |
| | KH$_2$PO$_4$ | | SSP | | DAP | | All-19 | | MAP | |
(mg L^{-1})	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)
10	6.5	35.0	4.6	54.0	4.7	53.0	5.0	50.0	4.8	52.0
20	13.0	35.0	9.3	53.5	9.6	52.0	12.1	39.5	9.7	51.5
30	21.7	27.7	13.8	54.0	14.5	51.7	19.8	34.0	17.5	41.7
40	31.1	22.3	19.7	50.8	20.5	48.8	28.0	30.0	23.9	40.3
50	40.0	20.0	25.5	49.0	25.8	48.4	37.0	26.0	31.4	37.2
60	50.3	16.2	31.5	47.5	34.0	43.3	45.5	24.2	41.3	31.2
70	59.6	14.9	39.0	44.3	43.1	38.4	54.4	22.3	50.8	27.4
80	70.1	12.4	45.6	43.0	53.0	33.8	63.9	20.1	60.3	24.6
90	80.0	11.1	54.4	39.6	62.5	30.6	73.3	18.6	69.0	23.3
100	89.8	10.2	59.0	41.0	73.2	26.8	84.4	15.6	78.8	21.2
110	100.7	8.5	69.8	36.5	83.4	24.2	94.6	14.0	92.0	16.4
120	112.0	6.7	80.8	32.7	93.6	22.0	104.6	12.8	101.9	15.1
130	124.2	4.5	90.9	30.1	103.8	20.2	114.9	11.6	112.9	13.2
140	134.7	3.8	102.9	26.5	114.1	18.5	125.2	10.6	126.3	9.8
150	146.0	2.7	113.6	24.3	124.2	17.2	135.6	9.6	135.8	9.5
SEd	3.97	-	4.47	-	5.36	-	5.71	-	5.38	-
CD	7.49**	-	9.13**	-	10.94**	-	11.66**	-	10.98**	-

SEd – Standard Error of mean difference;
CD expressed at P=0.05; Significance noted at 5% (*) and 1% (**) levels
RP- Recovered P (water soluble P in solution); PP-Precipitated P (insoluble P suspended in solution)

Table 4: Effect of saline water on precipitation of P in phosphatic fertilizers

| Added P | Sources of fertilizer phosphorus | | | | | | | | | |
| | KH$_2$PO$_4$ | | SSP | | DAP | | All-19 | | MAP | |
(mg L^{-1})	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)	RP (mg L^{-1})	PP (%)
10	2.7	73.0	0.2	98.0	1.9	81.0	2.7	73.0	2.6	74.0
20	9.7	51.5	0.6	97.0	4.2	79.0	9.0	55.0	9.1	54.5
30	17.6	41.3	3.0	90.0	6.4	78.7	16.1	46.3	15.7	47.7
40	25.5	36.3	5.6	86.0	9.0	77.5	23.2	42.0	23.7	40.8
50	34.0	32.0	8.4	83.2	11.4	77.2	31.0	38.0	33.4	33.2
60	42.4	29.3	11.6	80.7	18.3	69.5	39.4	34.3	40.5	32.5
70	51.6	26.3	15.9	77.3	24.3	65.3	47.4	32.3	49.3	29.6
80	60.6	24.3	20.9	73.9	28.5	64.4	57.0	28.8	57.5	28.1
90	69.0	23.3	27.4	69.6	34.3	61.9	65.6	27.1	66.4	26.2
100	77.8	22.2	36.7	63.3	43.5	56.5	76.4	23.6	75.7	24.3
110	87.4	20.5	45.1	59.0	52.8	52.0	86.5	21.4	85.4	22.4
120	101.4	15.5	58.9	50.9	73.1	39.1	96.8	19.3	95.3	20.6
130	114.2	12.2	70.4	45.8	84.5	35.0	106.9	17.8	106.9	17.8
140	130.4	6.9	82.7	40.9	95.3	31.9	116.6	16.7	118.9	15.1
150	142.7	4.9	93.2	37.9	103.9	30.7	127.2	15.2	129.5	13.7
SEd	3.65	-	4.14	-	4.68	-	5.27	-	4.81	-
CD	7.45**	-	8.45**	-	9.55**	-	10.76**	-	10.98**	-

SEd – Standard Error of mean difference;
CD expressed at P=0.05; Significance noted at 5% (*) and 1% (**) levels
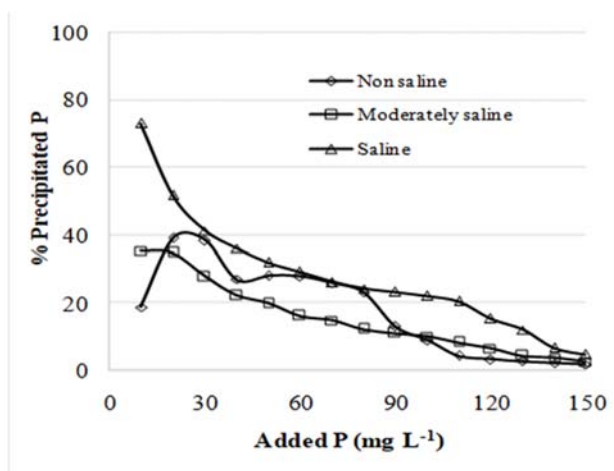RP- Recovered P (water soluble P in solution); PP-Precipitated P (insoluble P suspended in solution)

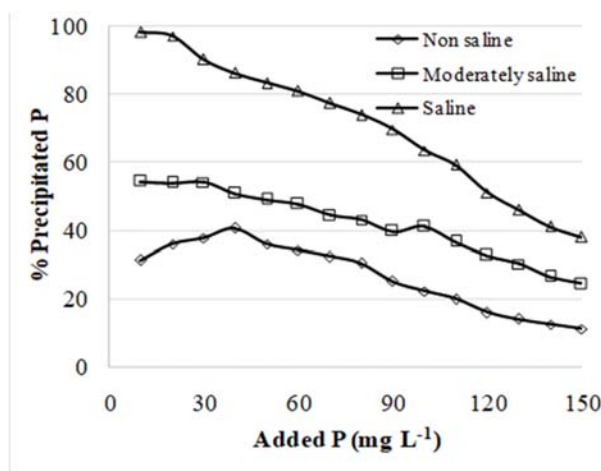**Fig 1:** Potassium dihydrogen phosphate
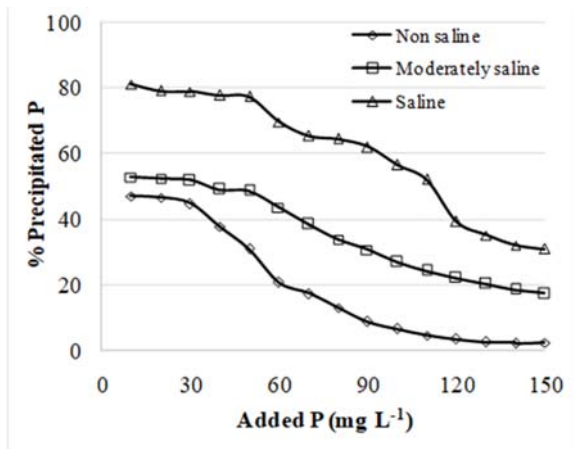

Fig 2: Single super phosphate

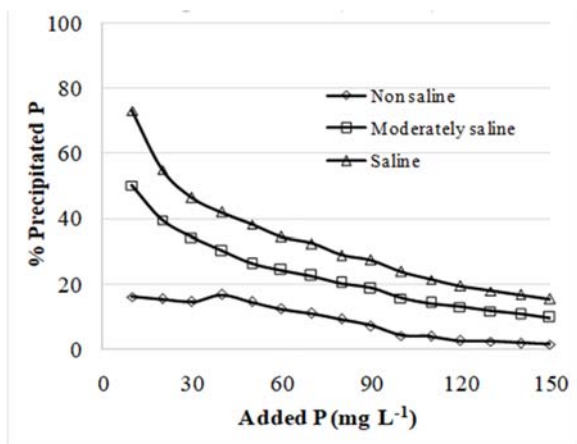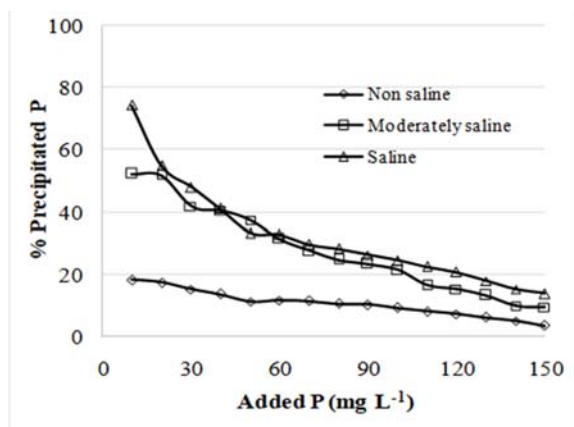**Fig 3:** diammonium phosphate

Fig 4: all – 19 (19:19:19)

Fig 5: Monoammonium phosphate

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