

28 The fixation of phosphorus (P) as calcium phosphates in alkaline soils is defined as a historical problem of soil science [1]. This
29 historical problem corresponds to very low phosphorus use efficiency (PUE) of applied P-fertilizer into the soil system even after
30 applied the best cultural practices. Along with low PUE, the deficiency of P in soils across the globe is also wide-spread with 43% of
31 the world soils being P-deficient [2]. In addition, most of P-fertilizers applied to soil system are derived from rock phosphates (RP)
32 which is a finite, non-renewable natural resource with an estimated life-span of 105-470 years [3]. Current levels of food production is
33 not possible without this finite storage and considering long-term food security it is imperative that the use of rock phosphate (RP) in
34 sustainable and equitable manner is not only intra-generation matter but also an inter-generational perspective [4]. Several studies
35 deal with concerns about the longevity of the supply of the mineral phosphate [5]. The finite nature of the RP reserves along with the
36 low use efficiency have triggered many research to improve the PUE from different P sources along with exploiting the low-grade P
37 reserves of poor economic viability to find some alternative source to the costly P-fertilizers.

38 The recent advancements in P-fertilizers involves coating of soluble P sources such as mono-ammonium phosphate (MAP) and di-
39 ammonium phosphate (DAP) with hydrophobic or partially hydro-philic compounds [6] or mixture with superabsorbent [7], nano-
40 sized clay particles [8, 9] or RP mixed with organic acid loaded nano clay polymer composites [10-12]. These technologies have
41 proved to be promising alternative sources to the costly P-fertilizers as well as improved the PUE but have not yet been adopted at
42 large scale. Besides these, the recent development in smart fertilizer delivery systems or the new generation fertilizers is a good
43 alternative to commercially available P fertilizers to improve the PUE and therefore, enhance resource utilization [13, 14].

44 The control release fertilizer (CRF) is the kind of new generation fertilizer which is designed to release plant nutrients in a
45 steady manner so as to synchronize the release with crop demand [15]. This technology not only helps in improving the nutrient use
46 efficiency but also suggests a suitable mechanism to reduce environmental hazards posed by indiscriminate and excessive use of
47 fertilizers [16, 17]. In general, CRF exhibit numerous preferences over the traditional water soluble fertilizers, for example, savings in
48 huge quantities of fertilizers, reducing the rate of release of fertilizer nutrients and thus supplying nutrients to crops for longer period
49 of growth, and increase CRF [18]. In the recent, there is renewed interest to establish this concept for developing new CRF. One of
50 the possible means of applications of CRF is to apply them in association with super-absorbent which is able to release their nutrient

51 in a controlled manner [19]. Also, various coating agents can be employed to regulate the nutrient release. Roy et al., [20] reported
52 that, polymer coating of mono-ammonium phosphate (MAP) granules increased the fertilizer PUE up to 32.6%.

53 Therefore, attempts by several research groups to overcome such problem have been examined. The use of slow or controlled
54 release fertilizer (CRF) was used and in this technique, the P fertilizer is generally fixed to a matrix, usually a polymer, and released
55 at a slower rate. However, very limited studies are available on the development and evaluation of CRF in arid and semi-arid soils. In
56 this study, we investigated the assessment and evaluation of phosphorylated alginate controlled release properties in laboratory and
57 incubation experiments compared with conventional water soluble P-fertilizers like mono-ammonium phosphate (MAP) and di-
58 ammonium phosphate (DAP).

59

60 **2. MATERIALS AND METHODS**

61 **2.1 Fertilizers**

62 To improve phosphorus use efficiency, two fertilizers types of phosphate-bound alginate-graft-polyacrylamide (P-Alg-g-PAM) were
63 prepared using mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP) fertilizer. A matrix of sodium alginate (Alg)
64 and polyvinyl alcohol (PVA) was phosphorylated using either MAP or DAP fertilizer, followed by grafting with acrylamide. Slow-
65 release phosphate-bound alginate-graft-polyacrylamide (P-Alg-g-PAM) using mono-ammonium phosphate (MAP) and di-ammonium
66 phosphate (DAP) were developed and characterized.

67

68 **2.2 Soil**

69 Three soils was collected from different locations based on CaCO_3 content; the 1st soil was collect from the Experimental and
70 Research Farm at Dirab, 25 km from South Riyadh, while the 2nd and 3rd samples collected from Al Kharj city 80 km from South east
71 of Riyadh.

72 **2.3 Soil Analysis**

73 The collected samples were air-dried, ground and passed through a 2-mm sieve. Total carbonate was estimated according to [21].
74 Total soluble salts were determined by measuring the electrical conductivity (EC) of saturated soil paste extract as described by [22].
75 Soil pH was determined through a suspension sample with a soil air-dried to water (w/w) ratio of 1:2.5 and measured with a pH-
76 meter. Soil organic matter was determined by wet oxidation [23]. Available concentrations of N, P and K were extracted and
77 determined as described by [24]. Particle size distribution of soil was carried out using the pipette method as described by [25]. Some
78 physical and chemical properties of the different soil are presented in (Tables 1a, 1b and 1c).

79 **2.4 Incubation Experiment**

80 An incubation experiment was carried out to evaluate the release of P into soils from MAP-uncoated, DAP-uncoated, MAP-modified
81 Alg-g-PAM (refer to MAP + polymer) and DAP-modified Alg-g-PAM (refer to DAP + polymer) at the Soil Science Department, Faculty
82 of Agriculture and Food Sciences, King Saudi University, Saudi Arabia. The experiments were carried by using 1 g of phosphorylated
83 alginate. The experiment was conducted with 3 soils with different CaCO₃ content (14%, 33% and 43%) and 4 fertilizer types (MAP-
84 uncoated, DAP-uncoated, MAP + polymer and DAP + polymer) in a completely randomized design (CRD) with three replications. In
85 brief, 1 g of fertilizer was mixed with 200 gm air-dried soil in a 250 ml glass beaker. After incorporation of the granules, soil moisture
86 was maintained to 75% of water-holding capacity and was maintained constant during the incubation period with the addition
87 whenever necessary. The samples were incubated at a controlled temperature of 25°C for 1, 5, 15, 20, 25, and 30 days. After each
88 incubation period, destructive soil samples were drawn and extracted by Olsen reagent (0.50 M NaHCO₃, at pH 8.50) as per the
89 procedure outlined by [26] followed by estimation of P in the extract by ascorbic acid blue colour method [27] using a single beam
90 spectrophotometer (9100 UV-vis Model).

91

92 **2.5 Sequential P Fractionation**

93 Another experiment was conducted to determinate the sequential P fractionation using the same soils. The samples in previous
94 experiment were incubated at 25°C and 70% of soils field capacity. Represented sub-soil samples were collected at 5, 15, and
95 30 days after incubation and analyzed for P sequential fractionation. A sequential P fractionation method described by [28] with
96 a slight modification, as outlined by [29]. Briefly, (1 g) soil sample was extracted with 25 mL of 0.50 M NaHCO₃ solution and
97 shaken for 16 hours, and then the solution was centrifuged at 4000 rpm for 10 minutes to extract soluble and exchangeable-P
98 and the remaining soil sample was then saved for subsequent extractions. The P bound to Al and Fe hydroxide minerals was
99 extracted by adding 25 mL of 0.10 M NaOH solution to the soil sample from the previous extraction and shaken 16 hours. The
100 solution was then centrifuged at 4000 rpm for five minutes and analyzed for Fe and Al phosphate concentration. The Ca-bound
101 P was extracted by adding 25 mL of 1.0 M HCl to the soil sample and shaken 16 hours. The supernatant was then centrifuged
102 at 4000 rpm for five minutes and analyzed for Ca phosphate concentration. The residual P was digested by adding 10 mL of
103 concentrated HNO₃ to the soil sample according to the EPA method [30].
104

105 **2.6 Statistical Analysis**

106 The statistical analysis was done using Statistical analytics platform v13.1. The significance of the differences was evaluated by
107 using one-way analysis of variance (ANOVA). Where *P* value <0.05 was considered as statistically significant.
108

109 **3. RESULTS AND DISCUSSION**

110 **3.1 Properties of Slow-release MAP, DAP and Soil**

111 The physical and chemical properties of soil used in this study are listed in Tables 1a, 1b and 1c. The soil texture was sandy loam
112 and sandy clay loam, the soil pH was varied from 7.20 to 8.40 and with EC value ranged from 0.30, 2.17 and 7.20 dS m⁻¹ in soil-1,
113 soil-2 and soil-3, respectively. In addition, results indicated that the percentage of CaCO₃ was relatively high and varied from 14%,
114 33% and 43% in soils-1, soil-2 and soil-3, respectively, which is considered the most critical factor to fix phosphorus as calcium

115 phosphate, which will not be available for plant uptake. Also the P fractions of original soil at start of the experiment varied among the
116 soil (Tables 1a, 1b and 1c).

117 **3.2 Available Soil-Phosphorus**

118 Influence of addition of uncoated MAP, uncoated DAP, slow-release MAP and slow-release DAP on soil available-P are presented in
119 Table 2, Figures 1, 2 and 3. Results from laboratory incubation experiments indicated that the available soil-P significantly ($P < 0.05$)
120 varied between the different P fertilizers. The available P into different soil from coated slow-release MAP and DAP was lower
121 throughout the incubation period than the commercial MAP and commercial DAP. The results demonstrated that the soil available-P
122 differs widely among the fertilizer type and decreased substantially with time of incubation. The addition of MAP and DAP chemical
123 fertilizers increase the amount of available P in the different soil in the day to 5 days after incubation and then decreases as time of
124 incubation goes on. The decreases in soil available-P may be attributed to time-dependent reactions involving the sorption and
125 precipitation of added and native P [31-33]. Figure 4 shows effects of soil type on P availability during the different incubation
126 periods. The results indicated that the soils with different CaCO_3 , the available soil-P significantly ($P < 0.05$) varied between the
127 different soil in which soil-1 resulted in higher amounts of available soil-P compared with soil-2 and soil-3. The results found a highly
128 negative correlation ($R^2 = 0.913$) between available soil-P and CaCO_3 content in soil (Figure 4).

129 **3.3 Phosphorus Release Behavior**

130 Slow-release of P is the most important property. Phosphorus release behavior of coated slow-release MAP and DAP in different
131 soils. Figures 5, 6 and 7 show a plot of the released P against incubation period. Results emanated from laboratory incubation
132 experiments indicated that P release into different soil from coated slow-release MAP and DAP was lower throughout the incubation
133 period than the commercial MAP and commercial DAP. About 80% of phosphate was released into soil from the commercial MAP
134 and commercial DAP fertilizer by the 5 days after incubation as presented in. Compared with the uncoated MAP and uncoated DAP
135 fertilizer, the release rate of P from different soil as shown in Figures 5, 6 and 7 decreased sharply, but still obviously higher than that
136 from the slow-release MAP and slow-release DAP fertilizers. This indicated that the coated slow-release MAP and slow-release DAP
137 had a good slow-release-property, which agreed with the standard of slow-release fertilizers of the committee of European

138 Normalization [34, 35]. The results indicated that, the fertilizers could be classified into two groups: the first “fast release” group
139 showed total P release in the 10 days after incorporation of uncoated MAP and uncoated DAP fertilizers into soil (Figures 5, 6 and 7).
140 The second “slow release” group showed release of around 70% during the incubation periods between 10 and 30 days after
141 incubation and included coated slow- release MAP and coated slow- release DAP fertilizer (Figures 5, 6 and 7). It is well-known that
142 phosphate would dissolve quickly in the water after being added into the soil, and the P in it released into soil. The slow-release MAP
143 and slow-release DAP would dissolve slowly due to an increase in chain length. The coating superabsorbent MAP and DAP
144 polymers would absorb water slowly in soil and swell after being added into soil, which would contribute to an increase in the pore
145 size of the three-dimensional network and benefit the diffusion of the fertilizer solution in the hydrogel network. MAP and DAP in the
146 core of coated slow-release MAP and DAP fertilizer would dissolve slowly in water absorbed in the swollen hydrogel network. There
147 exists a dynamic exchange between the free water in the hydrogel and one in soil [36] , and then the fertilizer would release slowly
148 into the soil through the grids with dynamic exchange [37, 38].

149 The variation in P release pattern into soil under controlled temperature was observed during the incubation. The release of P from
150 different soil followed in the decreasing order of soil-1 > soil-2 > soil-3. The coating superabsorbent polymers MAP and DAP would
151 absorb slowly the water in soil and swell after being added into soil, which would contribute to an increase in the pore size of the
152 three-dimensional network and benefit the diffusion of the fertilizer solution in the hydrogel network [36, 39]. The results indicated
153 that, the release rate of P from the coated materials into soil was significantly lesser than the commercial DAP under controlled
154 laboratory conditions which establishes the slow- release behavior of the coated slow- release MAP and coated slow- release DAP
155 fertilizer which are likely to reduce P-fixation in soil and maintain a higher amount of bio-available P in soil solution, thus supply P to
156 crops over a long times. The coated slow- release MAP and coated slow- release DAP fertilizer released lesser amounts of P
157 presumably because of reduction of effective surface area available for contact between the core of manufactured products and the
158 soil. This might be the reason for slow- release coating materials to slow down the movement of P into the soil and also reduce the
159 volume of the soil in contact with manufactured coated products. This result is in agreement with the results of [35]. He and Hu [40]
160 synthesized a novel water insoluble slow release fertilizer, biuret poly phosphoramidate using urea, phosphoric acid and ferric oxide,
161 which contain 5.6% N and 11.7% P. Their results indicated that the product not only had good slow release property and excellent

162 water retention capacity but also higher adsorption capacities of cations in saline soil. Throughout the incubation period, the extent of
163 release rate of P varied from different products indicating their differential release pattern which directly or indirectly depends on type
164 of acids, coating agents, coating levels, contact time between soil and applied P sources, temperature and soil moisture content [41].
165 Irrespective of coating agents, soil-1 had released significantly higher amount of P than the other soil-2 and soil-3 during each
166 interval of sampling. Between the two coating agents, there was distinct variation in release of P during incubation experiments. As
167 presented in figures 5, 6 and 7, it observed that MAP coated polymer released higher amount of P over the DAP coated polymer at
168 different incubation period. The data in tables and figures shows that after 10 days from the incubation, the P release rate of MAP
169 coated polymer and DAP coated polymer was higher than the commercial MAP and DAP. The fast releasing P-fertilizers supports
170 better root establishment, but this might be depended on the concentration of solution P instead of total P present in soil. Commercial
171 MAP and DAP fertilizers released its entire active-P into soil too early compared to the establishment time of root and formed
172 insoluble inert initial reaction products in soil. However, the controlled release fertilizer (CRF) are able to release their nutrient
173 contents gradually which coincide with the nutrient requirement of the plants [19]. Timothy et al., [42] reported that release rates of P
174 from CRF products were slower than those for $\text{NH}_4^+\text{-N}$, $\text{NO}_3^-\text{-N}$. Improved growth and yield with CRF compared with soluble MAP
175 and DAP fertilizers have been documented in potato [43].

176 **3.4 Soil-Phosphorus Fractions**

177 Tables 3a, 3b and 3c present the effects of fertilizers types and incubation periods on P fractions, which include the soluble and
178 exchangeable-P, Al and Fe-bound- P, Ca-bound- P, and residual- P as discussed below. The results indicated that soluble,
179 exchangeable-P, Al and Fe-bound- P, Ca-bound- P, and residual- P varied among different soils and fertilizers type. In soil-1, 2 and
180 3 and 5 days after incubation, the uncoated MAP fertilizer exhibited the highest concentration of soluble and exchangeable-P and Ca-
181 bound- P compared with other P fertilizers. Similar trend were observed at 15 and 30 days of incubation. The results indicated that
182 the amount of the Al-Fe P fraction was very low compared to other P fractions. This caused by the high original concentration of Ca
183 in studied soil which ranged from 14% to 43%, which was responsible for determining the ion speciation in the soil solution [44]. The
184 results indicated that, Ca-occluded P fraction is the main P fraction in the studied soil and ranged from 50.0% to 60% from the total P
185 concentration. This supports the earlier observations that most Saudi soils are dominated by the Ca-P fraction [45, 46].

186 **4. CONCLUSIONS**

187 The slow-release MAP and slow-release DAP was prepared to supply P to the plant at a controlled release rate and to increase the
188 phosphorus fertilizer use efficiency (PFUE) under calcareous soil condition. The results concluded that, the developed MAP and DAP
189 fertilizers could be considered as slow-release for deliver P to the plant for long time compared with uncoated MAP and DAP and
190 therefore could be increase the phosphorus use efficiency under calcareous soil conditions. The results indicated that there were
191 significant differences between the effects of different P fertilizer types on soluble + exchangeable- P, Ca-occluded P fraction,
192 residual-P fraction, Fe& Al-occluded P fraction and total P.

193

194 **COMPETING INTERESTS**

195 Authors have declared that no competing interests exist.

196

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302 Table 1a. Physico-chemical properties and P fractionation of original (Soil 1) at the start of experiment

pH	Ec (dS m ⁻¹)	OM	CaCO ₃	Cations				Anions				Available Nutrients						Particle Size Distribution			Texture Class
				Ca ⁺²	Mg ⁺²	Na ⁺¹	K ⁺¹	Cl ⁻¹	HCO ₃ ⁻¹	CO ₃ ⁻²	SO ₄ ⁻²	N	P	K	Fe	Zn	Cu	Mn	Sand	Silt	
7.50	0.3	%		(meq L ⁻¹)								(mg kg ⁻¹)						%			Sandy loam
		0.22	14	4	3	11.36	13.65	3.4	3.6	0.00	10.3	2.70	3.12	66.8	2.24	0.42	0.12	1.02	76	8	
Phosphorous fractionation (mg kg ⁻¹)																					
NaHCO ₃ -P (Soluble and exchangeable – P)				NaOH-P (Fe & Al -P)				HCl-P (Ca -P)				Residual - P			Total- P						
8.69				6.00				227.7				31.35			273.7						

303

304 Table 1b. Physico-chemical properties and P fractionation of original (Soil 2) at the start of experiment

pH	Ec (dS m ⁻¹)	OM	CaCO ₃	Cations				Anions				Available Nutrients						Particle Size Distribution			Texture Class
				Ca ⁺²	Mg ⁺²	Na ⁺¹	K ⁺¹	Cl ⁻¹	HCO ₃ ⁻¹	CO ₃ ⁻²	SO ₄ ⁻²	N	P	K	Fe	Zn	Cu	Mn	Sand	Silt	
7.20	2.17	%		(meq L ⁻¹)								(mg kg ⁻¹)						%			Sandy Clay loam
		3.4	33	21.4	4.6	14.76	60.45	4.6	5.20	0.00	14.3	6.23	2.60	89.3	1.9	0.41	0.12	1.2	60	16	
Phosphorous fractionation (mg kg ⁻¹)																					
NaHCO ₃ -P (Soluble and exchangeable – P)				NaOH-P (Fe & Al -P)				HCl-P (Ca -P)				Residual - P			Total- P						
5.94				5.08				317.9				71.65			400.6						

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307 Table 1c. Physico-chemical properties and P fractionation of original (Soil 3) at the start of experiment

pH	Ec (dS m ⁻¹)	OM	CaCO ₃	Cations				Anions				Available Nutrients						Particle Size Distribution			Texture Class
				Ca ₊₂	Mg ⁺²	Na ⁺¹	K ⁺¹	Cl ⁻¹	HCO ₃ ⁻¹	CO ₃ ⁻²	SO ₄ ⁻²	N	P	K	Fe	Zn	Cu	Mn	Sand	Silt	
8.40	3.50	%		(meq L ⁻¹)								(mg kg ⁻¹)						%			Sandy loam
		0.27	43	19.7	11.0	3.20	0.44	11.4	0.50	0.00	23.1	4.80	2.60	56.5	2.78	0.32	0.17	1.15	70.3	16.0	
Phosphorous fractionation (mg kg ⁻¹)																					
NaHCO ₃ -P (Soluble and exchangeable – P)				NaOH-P (Fe & Al -P)				HCl-P (Ca -P)				Residual - P			Total- P						
3.68				7.13				198.2				62.0			271.0						

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UNDER PEER REVIEW

313 Table 2. The soil available-P from the prepared phosphorus fertilizer compared with uncoated MAP and DAP in different soil at
 314 different time of incubation

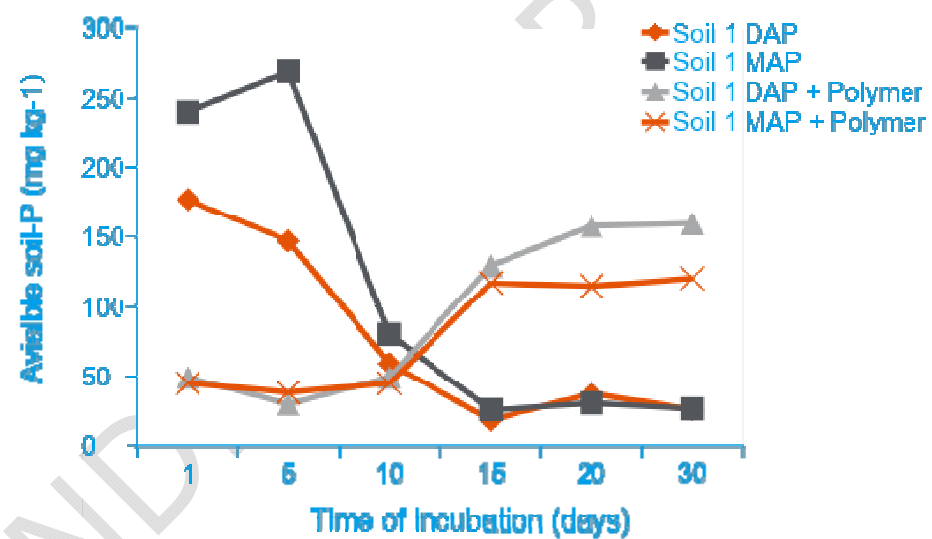
Treatments		Available Phosphorus (mg kg ⁻¹)						Mean	Mean
		1 Day	5 Days	10 Days	15 Days	20 Days	30 Days	LSD _{0.05} = 12.0	LSD _{0.05} = 6.6
*Soil-1	DAP-uncoated	176.7	146.8	58.9	18.2	37.1	25.6	77.2 c	92.3 a
	MAP-uncoated	239.7	268.7	79.9	25.5	30.3	26.3	111.7 a	
	DAP + Polymer	48.9	29.6	48.9	129.2	157.7	159.5	95.6 b	
	MAP + Polymer	44.6	38.0	44.6	116.8	114.5	120.0	79.8 c	
Soil -2	DAP-uncoated	194.4	125.8	59.9	14.6	27.7	19.3	73.6 c	88.4 ab
	MAP-uncoated	221.7	213.8	73.9	21.6	30.6	28.6	98.4 b	
	DAP + Polymer	60.8	52.6	60.8	130.3	150.0	155.6	101.7 ab	
	MAP + Polymer	59.7	46.7	71.3	140.8	122.0	125.5	94.3 b	
Soil- 3	DAP-uncoated	184.9	131.8	66.5	16.9	29.8	27.3	76.2 c	82.4 b
	MAP-uncoated	219.8	204.5	77.9	26.5	41.2	32.3	100.4 ab	

	DAP + Polymer	44.8	32.9	54.7	108.0	138.8	140.5	76.9 c
	MAP + Polymer	54.0	71.9	62.0	41.5	81.5	102.3	79.7 c
	Mean	129.2	1113.6	63.3 e	70.9	80.5 c	75.3	cd
	LSD _{0.05} = 8.5	a	b		de		cd	

315 *Soil 1, CaCO₃=14%; Soil 2, CaCO₃=33% and Soil 3, CaCO₃ =43%.

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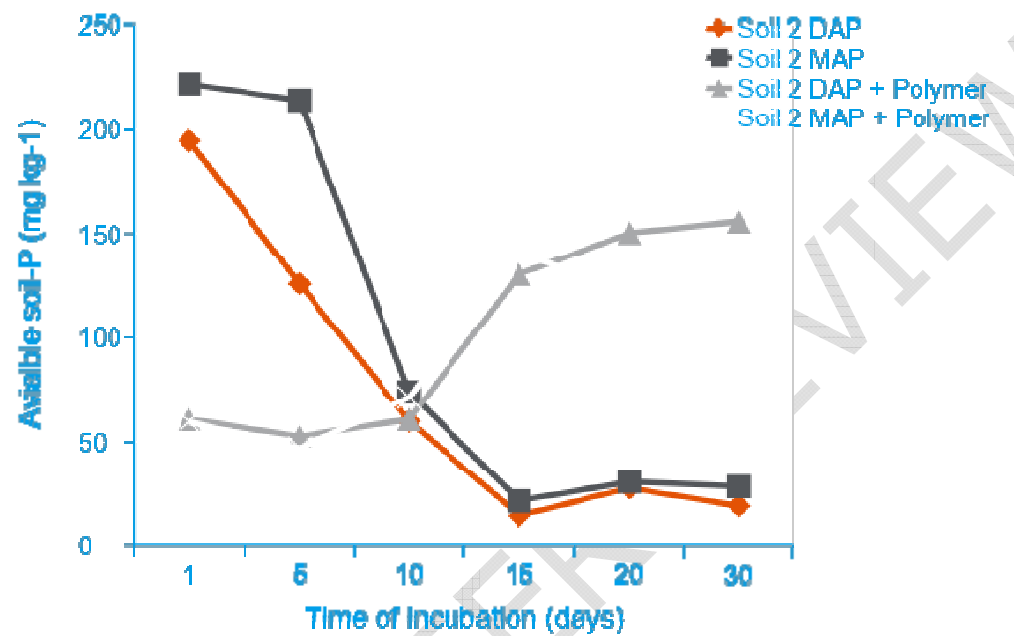
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319 Fig. 1. Available soil- P from uncoated MAP, uncoated DAP and coated MAP and coated- DAP in soil-1(CaCO₃=14%)

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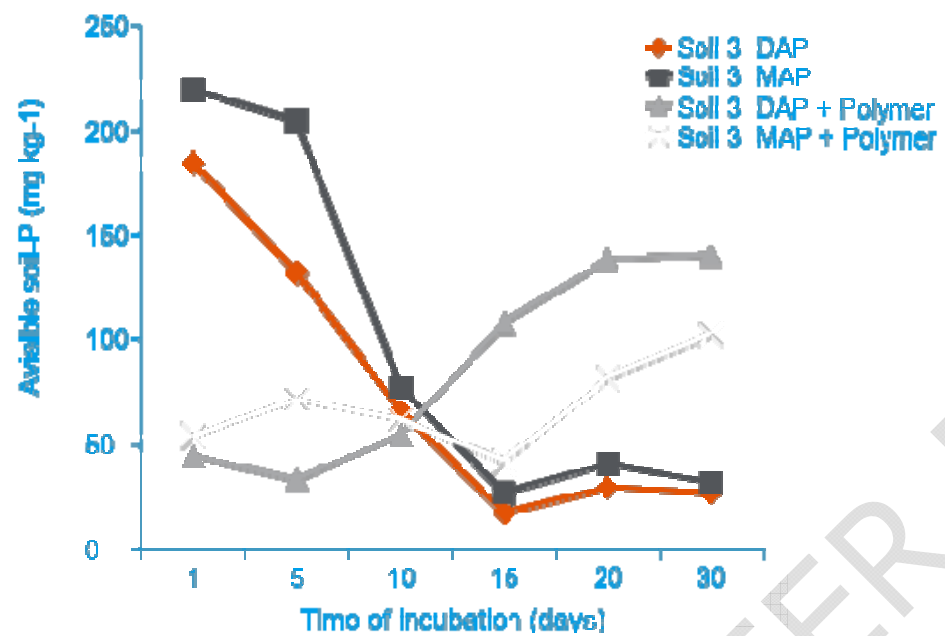


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322 Fig. 2. Available soil- P from uncoated MAP, uncoated DAP and coated MAP and coated- DAP in soil-2 (CaCO₃=33%)

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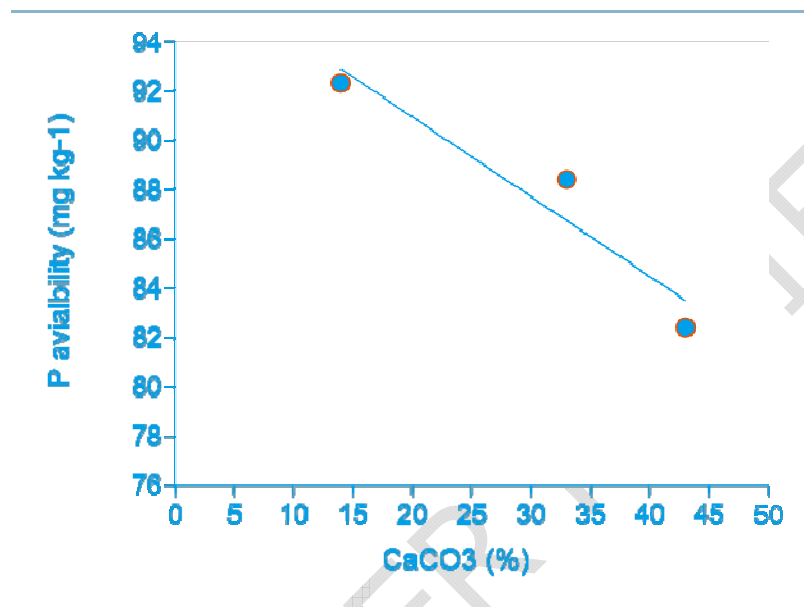


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326 Fig. 3. Available soil- P from uncoated MAP, uncoated DAP and coated MAP and coated- DAP in soil-3 (CaCO₃=43%)

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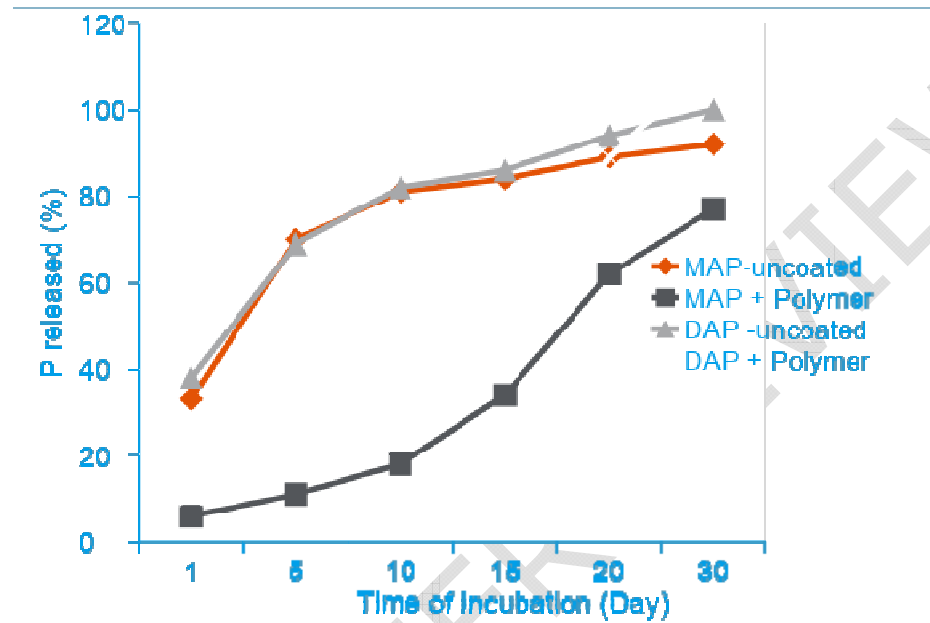


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330 Fig. 4. Relationship between available soil-P and CaCO₃ % in different soil

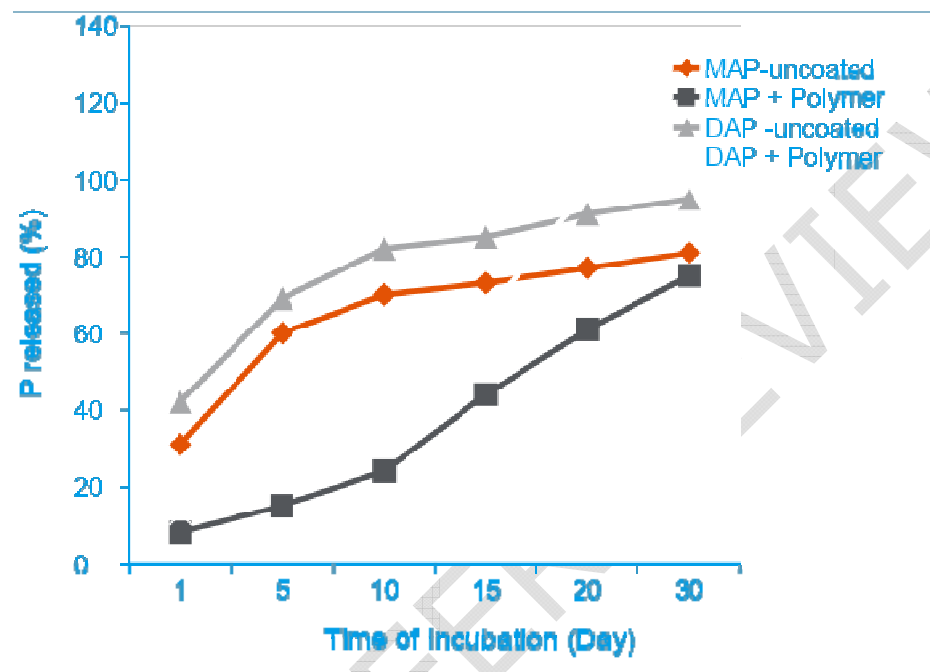
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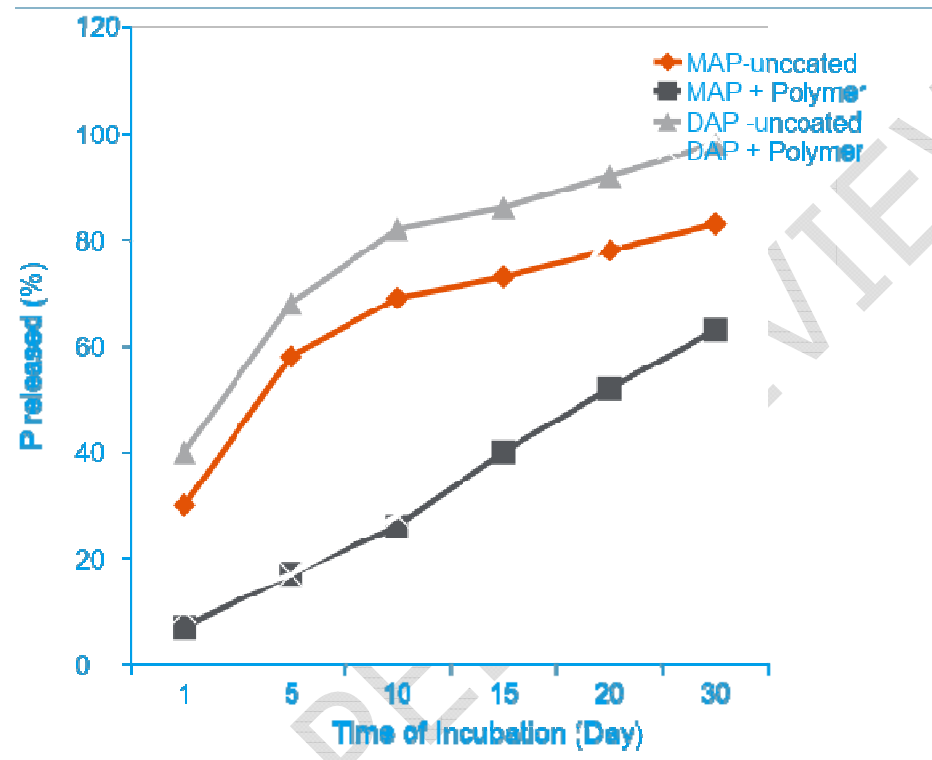
334 Fig. 5. Phosphorus release behaviour into soil-1 from commercial-MAP, commercial-DAP, slow-release MAP and slow-release DAP



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336 Fig. 6. Phosphorus release behaviour into soil-2 from commercial-MAP, commercial-DAP, slow-release MAP and slow-release DAP

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339 Fig. 7. Phosphorus release behaviour into soil-3 from commercial-MAP, commercial-DAP, slow-release MAP and slow-release DAP

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UNDER PEER REVIEW

343 Table 3a. P fractions as influenced by different fertilizers type at 5 days after incubation

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Treatments		Soluble and exchangeable P	Fe and Al-P	Ca -P	Residual P	Total P
		mg kg ⁻¹ (5 days after incubation)				
Soil-1	DAP	254.0	186.7	205.1	50.2	529.7
	MAP	403.0	222.5	228.4	42.2	697.1
	DAP + Polymer	130.6	40.9	207.1	25.7	310.2
	MAP + Polymer	118.1	52.0	172.0	20.0	279.1
Soil-2	DAP	239.7	207.8	380.5	75.0	706.9
	MAP	285.7	178.7	366.5	62.6	726.9
	DAP + Polymer	109.0	69.2	406.3	47.0	570.4
	MAP + Polymer	112.5	81.4	329.5	74.6	523.4
Soil-3	DAP	212.2	170.9	226.7	47.7	501.9
	MAP	229.1	262.8	197.0	82.2	518.5
	DAP + Polymer	121.3	24.9	196.7	40.7	320.8
	MAP + Polymer	147.5	37.5	189.8	100.5	379.2

345

346 Table 3b. Continued; P fractions as influenced by different fertilizers type at 15 days after incubation

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Treatments		Soluble and exchangeable P	Fe and Al-P	Ca -P	Residual P	Total P
		mg kg ⁻¹ (15 days after incubation)				
Soil-1	DAP	263.2	13.1	206.0	47.4	529.4
	MAP	375.7	11.7	213.0	47.6	647.5
	DAP + Polymer	31.3	9.4	213.5	46.5	300.4
	MAP + Polymer	59.0	14.7	177.5	53.2	298.7
Soil-2	DAP	185.7	12.5	487.0	68.8	749.3
	MAP	200.4	8.0	645.5	61.3	915.0
	DAP + Polymer	77.7	11.2	553.0	61.7	699.9
	MAP + Polymer	90.4	8.9	581.0	60.8	740.7
Soil-3	DAP	140.0	11.9	257.5	81.8	488.7
	MAP	192.5	8.9	207.5	38.9	447.8
	DAP + Polymer	40.8	4.9	248.5	43.2	337.2
	MAP + Polymer	53.6	9.5	194.5	23.5	278.0

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349 Table 3c. Continued; P fractions as influenced by different fertilizers type at 30 days after incubation

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Treatments		Soluble and exchangeable P	Fe and Al-P	Ca -P	Residual P	Total P
		mg kg ⁻¹ (30 days after incubation)				
Soil-1	DAP	186.6	12.8	305.3	44.2	549.0
	MAP	222.5	12.45	302.65	18.2	555.8
	DAP + Polymer	40.9	8.96	204	25.45	279.1
	MAP + Polymer	52.0	8.6	198.9	23.75	283.1
Soil-2	DAP	207.75	7.42	585	68.9	868.8
	MAP	178.65	6.44	672.3	32.45	890.1
	DAP + Polymer	69.15	10.265	589.5	30.1	698.6
	MAP + Polymer	81.4	8.265	550.5	34.4	674.4
Soil-3	DAP	170.9	10.58	217	56.5	455.2
	MAP	262.75	12.355	267.4	77.6	620.2
	DAP + Polymer	24.9	6.48	207	25.15	263.2
	MAP + Polymer	37.5	7.795	252	35.18	332.4
LSD _{0.05}		43.5	5.0	48.9	27.7	71.5

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