Agronomic Effectiveness of a New Formula of Phosphate Fertilizer
I - Initial Agronomic Effectiveness

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Abstract

A field experiment was conducted using corn (Zea mays var. Rabee) as a test crop to study the initial agronomic effectiveness of heavy single application of three sources of P fertilizers viz: TSP, PR, and M5 (a new formula consisted of PR + elemental sulphur of which 20% of sulphur was added as H_2SO_4) applied at four rates (0, 86, 172, 344 kg P .ha^{-1}) on corn yield and P uptake. Results showed a significant increase by M5 on grain yield, and the maximum grain yield was achieved at the rate of 172 kg P .ha^{-1} which did not differ significantly with 86 kg P .ha^{-1}. Dry weight yield did not differ significantly between the three sources. The dry weight yield increased by maximum when 86 kg P ha $^{-1}$ was added but the increase was not significant. M5 caused a maximum increase in P uptake compared with TSP and PR but the increase was not significant. Increasing the rate of application caused a significant increase in P uptake to the rate 172 kg P. ha^{-1}. Relative agronomic effectiveness (RAE) of the MS was 233 on the basis of grain yield compared with 100, 113, for TSP and PR, respectively. RAE of the MS was 133 on the basis of P uptake compared with 100, 89 for TSP, PR, respectively.

Key words: Agronomic effectiveness – Phosphate fertilizer – Phosphate rock – Triple super phosphate – initial effect.
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Introduction

Phosphorus (P) deficiency is one of the major factors limiting crop production in many soils. Despite the wide distribution of this element in nature its deficiency is widespread because most of the forms in which it occurs are poorly available to crops (Kato et a1., 1995; Hu et al., 1997). Younge & Plucknett (1966) mentioned that the problem of P fixation and low yield can be overcome by a heavy initial P treatments, which quenches the fixation complex and thus diverts the extra P to matrix yield product. The fixation capacity can, to some extent, be saturated resulting in a much slower rate of decline in available P and an expected long residual value of heavy application of P (Shelton & Coleman, 1968). In order to feed both the unsaturated soil and the crop, relatively high dressings of soluble phosphates have been applied normally 1.5 - 2.5 fold of the P - amount removed by cropping, as a consequence the P-status of the soil was continuously rising (Welte,1979). The heavy initial investment considered as a capital investment which can be settled over several years with continuance of residual effect (Engelstad, 1985).

There are vast regions of the world however, in which soluble fertilizers are not readily obtainable and where crop production is nowhere near maximum potential yields, in these regions, the goal is to increase crop production but not necessary to achieve the maximum yield, under these conditions use of phosphate rocks (PRs) of moderate to high activity can achieve this short - term goal of increasing crop production (Khasawneh & Sample, 1979). Phosphate rock (PR), which is a slow release phosphate fertilizer, is cheaper than triple super phosphate and has a longer residual effect (Hu et a1., 1997). According to the 1975 FAO Annual Fertilizer Review, direct application of PR accounted for only 5.0% of the total world consumption of 10.5 million metric ton of P in 1974 - 1975 and most of it used in the developing countries (Jiang et al., 1990).The quality factors for direct application are different, indeed, PR sources suitable for direct application are considered to be "problem ores" because of their low grade and the presence of accessory minerals impurities (Zapata & Roy, 2004). With respect to source with low or medium citrate solubility, it was found that row phosphate could be used to a better advantage for long-season crops than for short season crops (Brown & Jacob, 1945; Hammond, 1979). Additionally it has been shown that the efficiency of utilization of phosphorus from PR varies considerably with different crops (Hammond, 1979).

Zapata & Roy (2004) mentioned that the most important index used to express the agronomic performance of PR relative to water soluble P fertilizers is called the relative agronomic effectiveness (RAE) of a given P test fertilizer (Engelstad et al., 1974). This is determined by expressing as a percentage the ratio of the response of the test fertilizer (treatment - control) to the response of the standard fertilizers, when both are applied at the same rate:

$$RAE = \frac{Y_F - Y_C}{Y_R - Y_C} * 100 \qquad \text{(eq. 1)}$$

Where:

YF = average yield or P uptake obtained on all rates of applications of one of the tested fertilizers

Y_R= average yield or P uptake obtained on all rates of application of the reference fertilizers (TSP)

Yc= yield obtained in treatments without P additions

Based on the RAE equation different coefficients can be calculated for crop yield or dry matter production, P uptake, chemical extraction, or L values (Zapata & Roy, 2004). Different ways (chemical, biological, physical) were used to improve the agronomic effectiveness of PRs, one of the physical ways was the phosphate rock elemental sulphur assemblage (co granulating with sulphur) which, in some times, been inoculated with sulphur oxidizing bacteria to oxidize S to H_2SO_4, which in turn react with PR to release P (Engelstad, 1985). The objective of the following experiment (part 1) was to study the initial agronomic effectiveness of heavy single application of three sources of P fertilizers including the new formula M5 (Razaq et al., 2002) on P uptake and corn yield.

Materials and Methods

A field experiment was conducted to grow corn (Zea mays var. Rabee) in the field of soil and water resources center / Ministry of Science and Technology (MOST). Table 1 shows some characteristics of field soil before planting, where it is shown that the electrical conductivity (EC) of soil is 3.1 dS m^{-1} and the pH is neutral and tend to alkaline, available phosphorus (extracted with 0.5 M of NaHC03) is 10 mg .kg^{-1}. The table also shows that the texture of the soil is silty clay loam and classified as medium textured but it is on the boundaries between heavy and medium textured soils.The soil classified as sedimentary soil (Typic Torrifluvent).

This experiment represents the first in this study where corn was planted from July 2006 - Nov 2006. Plot dimensions were 2.0 x 2.5 m. Three sources of P were used for evaluation, Triple Super Phosphate (TSP), Phosphate Rock (PR), and the new formula phosphate fertilizer (M5) developed by Razaq et al.(2002), which was formulated by mixing 2:1 ratio of Phosphate Rock : elemental sulphur, of which 20% of S added was H_2SO_4. Rates of different sources of P fertilizers were, zero, 86, 172, 344 kg P. ha^{-1}. The rate 86 kg P. ha^{-1} represents the traditional fertilizing according to fertilizer recommendation guide for corn (Iraqi Ministry of Agriculture & Irrigation, 1992). Nitrogen was applied as urea according to fertilizer recommendation for corn, which compensate 300 kg urea. ha^{-1} at land preparation and 400 kg urea ha^{-1} when plants reached 20 cm height. The phosphate fertilizers was mixed with the first dose of urea and incorporated with surface soil upon land preparation, where the second dose of urea was broadcasted. Corn seeds were grown on rows, 75 cm between row and another, 25 cm was left between plants. The design was a factorial experiment according to randomized complete block design (RCBD) with three replicates. Soil samples from plot soil were taken to determine available P (Olsen P) at zero time (at fertilization) then soil samples from plot soil were taken at harvest (end time) to determine available P (Olsen P). Available P was determined after extraction with 0.5 M of NaHC03 (Olsen P). P uptake by grain and straw was determined by Watanabe & Olsen method (1965) after wet digestion of plant material using HNO_3, H_2SO_4, $HCLO_4$ acids (Jackson, 1958). Grain yield and dry weight yield were measured for each treatment. Total P uptake by the whole plant was also calculated.

Table 1. Some characteristics of the soil used.

Property	Unit	Value
Electrical Conductivity (EC)	$dS.\ m^{-1}$	3.1
pH	-	7.7
Org. Matter	$g.\ kg^{-1}$	6.3
CaCO3 equivalent	$g.\ kg^{-1}$	310
Total N	$g.\ kg^{-1}$	2.6
Available P	$mg.\ kg^{-1}$	10
Texture		Silty Clay Loam
Sand	$g.\ kg^{-1}$	124
Silt	$g.\ kg^{-1}$	516
Clay	$g.\ kg^{-1}$	360

Results and Discussion

Grain yield

The effect of rate and source of applied P on grain yield is shown in Table 2 which shows that there was a significant increase (p=0.05) achieved by the new formula (M5) which advocated as possible alternative to TSP for corn (Bolland et al., 1992). The significancy of the increase elicit by M5 may be attributed to the fact that even with high Ca - potential in soil, grassy land reacts more aggressively against PR by reason of strong CO_2 pressure in the rooted soil layers and the increase in P availability resulted by the action of the new formula (M5) which consists S and H_2SO_4 which accelerate P availability (Welte, 1979). The two other sources of P (TSP and PR) did not differ significantly.

The grain yield increased with P rate and reached the maximum at the rate 172 kg $P.ha^{-1}$ then decreased at the rate 344 kg $P.ha^{-1}$. The rates 2 and 3 (86, 172 kg $P.ha^{-1}$) did not differ significantly which means that grain yield increase were significant even with the lowest rate of application (86 kg $P.ha^{-1}$).

Table 2. Grain yield of corn as affected by rate and source of applied P.

P rate (kg $P.ha^{-1}$)	Grain yield ($kg.\ ha^{-1}$)			
	TSP	PR	M5	Mean*
0	1568	1683	1365	1539 B
86	1821	1898	2364	2028 A
172	2150	2064	2426	2213 A
344	1517	1530	2096	1714 B
Mean*	1764 B	1794 B	2063 A	

* Means with the same letter are not significantly different with T test (p=0.05)
LSD o.os for Fertilizer = 240.01
LSD o.os for P rate = 277.14

Dry weight yield

Table 3 reported that the new formula M5 elicit an increase in dry weight yield over the two other sources of P but the increase was not significant (p=0.05). The results

were 19652 kg ha^{-1} for M5 compared with 17628 and 17572 kg.ha^{-1} for TSP and PR, respectively. The insignificancy shown here may be due to the higher biological activity in soils of neutral to alkaline reaction and the more contact of convertible organic matter, which cause a great probability that PR will show the same effectiveness as the highly soluble phosphates (Welte, 1979). Moreover, these results are in agreement with Hammond (1979) who reported that new phosphates could be used to a better advantage for long season than for short - season crops. Moreover the increase caused by PR and M5 over TSP must enhance the use of such sources in places or countries that possess a source of PR but lacks the industrial facilities to produce super and triple phosphates (Khasawneh & Sample, 1979). The dry weight yield of corn also influenced by the rate of applied P, it was increased by application of the second rate (86 kg P.ha^{-1}) but it was then decreased to 18580 and 17894 kg ha^{-1} for the rates 172 and 344 kg P.ha^{-1} respectively. The increase caused by the second rate was not significant at p=0.05 (Hammond, 1979).

Table3. Dry weight yield of corn as affected by rate and source of applied P.

P rate (kg P.ha^{-1})	Dry weight yield (kg P.ha^{-1})			
	TSP	PR	M5	Mean*
0	18653	14637	17667	16986 A
86	19856	21130	18042	19676 A
172	16365	17392	21992	18580 A
344	15638	17129	20915	17894 A
Mean*	17628 A	17572 A	19652 A	

*** Means with the same letter are not significantly different with T test (p=0.05)**
$LSD_{0.05}$ for Fertilizer= 3190.1
$LSD_{0.05}$ for P rate = 3683.6

P uptake by the crop

The effect of the three sources of P on amount of P uptake by the plant is illustrated in Table 4. The application of M5 caused an increase in P uptake over TSP and PR but this increase was not significant (p=0.05). Increasing the rate of application caused a significant increase in P uptake to the rate 172 kg P. ha^{-1} then decreased. The rate 344 kg P. ha^{-1} did not differ significantly with the rate 86 kg P. ha^{-1} although it was higher. The rate 344 kg P. ha^{-1} gave values similar to those obtained by TSP and PR at the rate 172 kg P. ha^{-1}.

Table 4. Amount of P uptake (from the whole plant of corn) as affected by rate and source of applied P.

P rate (kg P.ha)	P uptake (kg P. ha⁻')			
	TSP	PR	MS	Mean*
0	25.353	23.401	25.774	24.844 C
86	36.455	30.901	32.923	33.433 B
172	46.082	46.104	43.727	45.304 A
344	28.845	36.290	46.594	37.243 B
Mean*	34.186 A	34.174 A	37.267 A	

*** Means with the same letter are not significantly different with T test (p=0.05)**
$LSD_{0.05}$ for Fertilizer = 5.3357
$LSD_{0.05}$ for P rate = 6.1611

$NaHC0_3$ extractable P

Available P values as determined by Olsen method ($NaHCO_3$ -P) were significantly higher with TSP and M5 as compared with PR (Table 5). This is due to the fact that TSP is sparingly soluble fertilizer and M5 is a partially acidulated fertilizer enriched with sulphur (of which 20% of S was added as H_2SO_4) so they are superior to PR alone (Bolland et al., 1992; Medhi & De Datta, 1997). The rate of P application also had a significant effect (p=0.05) on NaHCO3 extractable P.

Table 5. Effect of rate and source of applied P on $NaHCO_3$ extractable P (Olsen P) at the end of season.

P rate (kg P.ha')	Extractable P (mg P. kg^{-1} soil)			
	TSP	PR	M5	Mean*
0	7.0	5.9	9.7	7.522 C
86	9.7	8.3	12.8	10.278 BC
172	12.8	10.5	13.6	12.289 B
344	20.6	12.0	16.5	16.356 A
Mean*	12.517 A	9.175	13.142	

*** Means with the same letter are not significantly different with T test (p=0.01)**
$LSD_{0.01}$ for Fertilizer = 3.3354
$LSD_{0.01}$ for P rate = 3.8514

Internal Efficiency (IE)

The relationship between yield of dried tops and the P concentration measured in the tops which called the Internal Efficiency IE (Bolland et a1., 1992) differed for the different P sources (Table 6). This indicates that the plants have different internal efficiency of P use curves for the different P fertilizers. That is once the P has been take up by the plants, the same P concentration or P content in the plant tops were generally related to different yields when P was derived from different fertilizers. The mean values for all the P rates indicate that M5 was superior for the highest IE, while values of IE for TSP and PR were nearly the same.

Table 6. Relationship between yield of dried tops and the P uptake in the dried tops (Internal Efficiency, IE of P use) for the corn experiment.

P rate (kg $P.ha^{-1}$)	Internal Efficiency		
	TSP	PR	M5
0	798	697	738
86	595	745	620
172	402	422	558
344	595	514	494
Mean*	597	594	602

$$\text{Internal efficiency} = \frac{\text{Yield of dried tops}}{\text{P uptake}} \quad \text{(eq. 2)}$$

Relative Agronomic Effectiveness (RAE)

Using TSP as the standard (100%) and on the basis of corn grain yield, RAE (eq. 1)

of the PR was 113 (Table 7) where there was a high increase in RAE of the M5 (233). This may be due to the industrial process of this source which combines both the partially acidulation by H_2SO_4 which works initially to supply P, and sulphur content which works later by eliciting acid formation to enhance P availability.

Table 7. Relative agronomic effectiveness of various phosphates depending on corn grain yield and P uptake.

P source	Grain yield	RAE*	P uptake	RAE*
TSP	1764	100	34.2	100
PR	1794	113	33.2	89
M5	2063	233	37.3	133

* After averaging the grain yield and P uptake over all rates, these values were calculated using the formula:

$$RAE = \frac{Y_F - YC}{Y_R - YC} * 100$$

[Engelstad et a1.,1974]

The results also showed, and on the basis of P uptake by corn, that RAE of the PR was 89 and there was an increase in RAE of M5 (133) over TSP (100) which was the standard. So, the highest RAE among all sources of P occurs with M5 regardless of the growth parameter used. These results may be explained by the difference in Internal Efficiency of P use. The RAE of the three sources followed the order: M5 > PR > TSP on the corn grain yield basis and M5 > TSP > PR on the P uptake basis. This is in agreement with Hammond (1979) work who reported that PR with high solubility is nearly as effective or superior as the TSP standard.

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الفعالية الزراعية لتركيبة جديدة من السماد الفوسفاتي

1. الفعالية الزراعية الأبتدائية

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الملخص

أجريت تجربة حقلية لزراعة الذرة الصفراء بهدف دراسة الفعالية الزراعية الأبتدائية لإضافات منفردة ثقيلة لثلاث مصادر فوسفاتية وهي : TSP و PR و M5 (تركيبة سمادية جديدة مكونة من الصخر الفوسفاتي والكبريت المعدني الذي أضيف 20% من بشكل حامض الكبريتيك) أضيفت بأربعة معدلات إضافة (0 و 86 و 172 و 344 كغم P .هكتار $^{-1}$). أظهرت النتائج زيادة معنوية باستعمال M5 في حاصل الحبوب وقد تحقق الحاصل الأقصى للحبوب بأضافة المعدل 172 كغم P .هكتار $^{-1}$ والذي لم يختلف معنوياً مع معدل الأضافة 86 كغم P .هكتار $^{-1}$. لم يختلف حاصل الوزن الجاف معنوياً بين المصادر السمادية الثلاث. إزداد حاصل الوزن الجاف الى حده الأقصى بأضافة المعدل 86 كغم P .هكتار $^{-1}$ ولكن الزيادة لم تكن معنوية. تحققت الزيادة القصوى في الفسفور الممتص بإستعمال M5 مقارنة بسماد TSP وPR ولكن الزيادة لم تكن معنوية. سببت زيادة معدل الأضافة زيادة معنوية في الفسفور الممتص وصولاً الى المستوى 172 كغم P .هكتار $^{-1}$. بلغت الفعالية الزراعية النسبية (RAE) على أساس حاصل الحبوب 233 للمصدر M5 مقارنة مع 100 و 113 لسمادي TSP و PR ،على التوالي. بلغت الفعالية الزراعية النسبية (RAE) على أساس الفسفور الممتص 133 للمصدر M5 مقارنة مع 100 و 89 لسمادي TSP و PR ، على التوالي.