EFFECT OF DIFFERENT LEVELS OF ROCK PHOSPHATE-SULPHUR GRANULE ON YIELD AND NUTRIENT AVAILABILITY

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ABSTRACT

Pot experiments conducted to study the effect of rock phosphate-elemental sulphur granule (RP-S° G) on the yield, nutrient availability and P fractions in soil revealed that application of RP-S° granule at the rate of 60 kg P₂O₅ ha⁻¹ recorded the highest yield of onion and blackgram. The availability of nutrients like N,P and S were increased due to the addition of 60 kg P₂O₅ ha⁻¹. There was no significant influence on the availability of K. At initial stage, the P fractions (NaCl TEA-P, NaOH-Pi) were increased at 60 kg level, but other fractions (NaOH-P₀, HCl-P and residual P) were increased due to 75 kg P₂O₅ ha⁻¹. Better residual effects were reflected in blackgram yield and nutrient availability. Addition of RP-S° granule at 75 kg P₂O₅ ha⁻¹ also performed well but its effect was on par with 60 kg P₂O₅ ha⁻¹.

INTRODUCTION

Phosphorus (P) is one of the critical nutrient elements which plays an important role in increasing crop growth and yield. Although phosphatic fertilizers are being used in maximizing agricultural production in developed countries, many developing countries like India do not have adequate levels of P in soils and also have low level of fertilizer P consumption leading to the reduction in crop yields.

It is estimated that India has about 260 Mt of rock phosphate (RP) deposits (FAO, 1994). Attempts are being made to utilize these indigenous RP as an alternate source of P fertilizers for direct application. However, direct application of RPs alone to non-acid soils is not considered beneficial. Under this soil condition, application of RP along with some bioinoculant/organic manures/elemental sulphur/pyrite may be beneficial since these are reported to increase the P availability to plants. (Mishra et al., 1980, Singh and Amberger, 1991). In this study the low grade Udaipur rock phosphate (URP) was mixed with elemental sulphur (S°) at 5 : 1 ratio and this product was tested in onion and blackgram crops.

MATERIAL AND METHODS

The soil is Typic haplustalf, sandy clay loam in texture; pH 7.7, organic carbon 0.43 per cent, available N 230 kg ha⁻¹, available P 10.1 kg ha⁻¹ (Olsen) and available K 616 kg ha⁻¹. The treatments include different levels of RP-S° granule viz., 0, 15, 30, 45, 60 and 75 kg P₂O₅ ha⁻¹ and was supplemented with N with 50 per cent as basal dose (30 kg ha⁻¹) and K (30 kg ha⁻¹) and the remaining 50 per cent of N was applied one month after planting. Treatments were replicated four times and experiment was laid out in a randomized block design. Five onion bulbs, (Var. Co.4) were planted in each pot. After the harvest of onion, a residual crop of blackgram (Var. Co.5) was raised. The available nutrients in soil were determined at harvest stage. The P fractions were determined at initial and final stage of crop growth (Bolan and Hedley, 1989).

RESULTS AND DISCUSSION

Nutrient availability: The highest availability of N (76.3 mg kg⁻¹) was recorded with the addition of RP-S° granule at 60 kg P₂O₅ ha⁻¹ which was at par with 75 kg P₂O₅ ha⁻¹ (Table 1).
Table 1. Effect of different levels of RP-S°G on pH and available nutrients (mg kg⁻¹) in soil at harvest stage of onion, (var CO.4)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>Available N</th>
<th>Available P</th>
<th>Available K</th>
<th>Available S</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁-Control</td>
<td>7.6</td>
<td>66.5</td>
<td>3.4</td>
<td>212.0</td>
<td>9.8</td>
</tr>
<tr>
<td>T-2 -RP-S°G @ 15 kg P₂O₅ ha⁻¹</td>
<td>7.5</td>
<td>71.4</td>
<td>4.3</td>
<td>216.3</td>
<td>14.7</td>
</tr>
<tr>
<td>T-3 -RP-S°G @ 30 kg P₂O₅ ha⁻¹</td>
<td>7.4</td>
<td>73.5</td>
<td>6.8</td>
<td>219.0</td>
<td>18.3</td>
</tr>
<tr>
<td>T-4 -RP-S°G @ 45 kg P₂O₅ ha⁻¹</td>
<td>7.4</td>
<td>74.2</td>
<td>8.3</td>
<td>217.8</td>
<td>21.6</td>
</tr>
<tr>
<td>T-5 -RP-S°G @ 60 kg P₂O₅ ha⁻¹</td>
<td>7.4</td>
<td>76.3</td>
<td>11.3</td>
<td>220.3</td>
<td>26.5</td>
</tr>
<tr>
<td>T-6 -RP-S°G @ 75 kg P₂O₅ ha⁻¹</td>
<td>7.4</td>
<td>75.6</td>
<td>10.6</td>
<td>219.0</td>
<td>27.2</td>
</tr>
<tr>
<td>S.E.(d)</td>
<td></td>
<td>1.03</td>
<td>0.24</td>
<td></td>
<td>1.12</td>
</tr>
<tr>
<td>C.D. (0.05)</td>
<td></td>
<td>2.19</td>
<td>0.52</td>
<td>NS</td>
<td>2.38</td>
</tr>
</tbody>
</table>

This might be due to the increased mobilization of atmospheric nitrogen in soil with P application (Manjaiah et al., 1995).

A significant increase in available P was observed up to 60 kg P₂O₅ ha⁻¹ but the concentration declined at 75 kg P₂O₅ ha⁻¹ level. The microbial oxidation of S° produced protons (H⁺) which dissolved RP-S° and increased the available P (Rajan, 1982; Bolan and Hedley, 1990). The organic compounds of chelating materials exuded by the onion roots probably helped the release of a greater amount of P soil (Shanmugam, 1988).

The P application at any level made no significant differences in the amount of available K in soil. Since the experimental soil contained high amounts of K and an equilibrium would have existed, P fertilization in turn, could have no bearing on the already existing large pool of available K.

Increase in level of RP-S° granule had a pronounced effect on soil available S. It may be due to the S in the RP-S° granule was released to the soil due to the oxidation of S° by Thiobacillus sp and made available to plants (Rajan, 1983) or due to the fact that SO₄²⁻ is adsorbed on soil less strongly that H₂PO₄⁻, the additions of P fertilizers to soil and release of S to the plant (Manjaiah et al., 1995).

Phosphorus fractions: Different P fractions in soil were significantly influenced by addition of different levels of RP-S° granule. The readily plant available P as extracted in NaCl TEA was increased substantially despite plant uptake, but the solution plus adsorbed P as extracted in NaOH decreased remarkably irrespective of levels of addition (Table 2).

Table 2: Effect of different levels of RP-S°G on P fractions in soil (mg kg⁻¹) (Mean)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Initial</th>
<th>After the harvest of Onion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NaCl-TEA-P</td>
<td>NaOH-TEA-P</td>
</tr>
<tr>
<td>T₁-Control</td>
<td>3.0</td>
<td>87.5</td>
</tr>
<tr>
<td>T-2 -RP-S°G @ 15 kg P₂O₅ ha⁻¹</td>
<td>3.8</td>
<td>92.5</td>
</tr>
<tr>
<td>T-3 -RP-S°G @ 30 kg P₂O₅ ha⁻¹</td>
<td>4.5</td>
<td>80.0</td>
</tr>
<tr>
<td>T-4 -RP-S°G @ 45 kg P₂O₅ ha⁻¹</td>
<td>4.3</td>
<td>85.0</td>
</tr>
<tr>
<td>T-5 -RP-S°G @ 60 kg P₂O₅ ha⁻¹</td>
<td>5.3</td>
<td>80.0</td>
</tr>
<tr>
<td>T-6 -RP-S°G @ 75 kg P₂O₅ ha⁻¹</td>
<td>4.8</td>
<td>77.5</td>
</tr>
<tr>
<td>S.E.(d)</td>
<td>0.66</td>
<td>2.3</td>
</tr>
<tr>
<td>C.D. (0.05)</td>
<td>1.4</td>
<td>NS</td>
</tr>
</tbody>
</table>

While the dissolution of RP resulted in increase in plant available P (NaCl TEA-P) and solution P (NaOH-P), the reduction in NaOH-PI was partly due to plant uptake and microbial immobilization or transformation into insoluble P. The small increase in organic P
(NaOH-Po) further confirmed the microbial immobilization (Mackay et al., 1986; Bolan and Hedley, 1989).

The RP-S⁰ granule at 60 kg P₂O₅ ha⁻¹ recorded the highest values of inorganic P (80.0 mg kg⁻¹) as well as organic P (26.3 mg kg⁻¹) both at initial and at harvest stage of onion. This might be due to high rate RP dissolution occurred at this level due to the acid production by S⁰ addition.

The amount of acid soluble inorganic P (apatite-P) as extracted in 1M HCl decreased markedly from 230.0·to 183.0 and 238.0 to 175.0 mg kg⁻¹ at 60 and 75 kg P₂O₅ ha⁻¹ respectively. The decrease in the concentration further confirmed the dissolution of RP. The H₃PO₄ produced during the oxidation of RP-S⁰ would have solubilized the acid soluble P fraction, which could have been subsequently utilized by the crop or lead to the increase of solution P. There was not much change in the concentration of residual P during later stage, which might be due to the fact that these fractions are highly insoluble and dissolution from this pool is particularly non-existent (Mahimairaja et al., 1995).

Yield of onion bulb: Application of RP-S⁰ granule at 60 kg P₂O₅ ha⁻¹ recorded the highest value of bulb yield (282 g pot⁻¹), but it was at par with addition of 75 kg P₂O₅ ha⁻¹ (275 g pot⁻¹). The slow and continuous release of P from RP due to the oxidation of S⁰ could be attributed to the better growth of onion. (Kandaswamy et al., 1985; Ravichandran, 1991; Mariappan, 1992). However, a decline in crop yield at 75 kg P₂O₅ ha⁻¹ may be due to lesser dissolution of RP-S⁰ at higher level of its application (Mahimairaja et al., 1995).

Residual effect on blackgram growth and yield: In the residual crop of blackgram, RP-S⁰ granule recorded higher yield attributing characters and yields of blackgram indicating the capability of RP in sustaining available P for longer time and better residual effect (Chandrasekaran, 1989). The grain yield of blackgram increased with increase in P levels up to 60 kg P₂O₅ ha⁻¹ indicating the stimulatory effect of P on dry matter production (Table 4). The addition of indigenous RP produced better performance, which may be due to the P release phased manner from Udaipur rock phosphate, (URP) (Mahimairaja and Raniperumal, 1995). It may be also due to the fact that P play a vital role in root proliferations, seed production, soil structure improve-

### Table 3: Effect of different levels of Rock phosphate-elemental sulphur granule (RP-S³G) on growth characteristics and yield of onion (Var CO.4) at harvest stage (Mean)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant Height (cm)</th>
<th>Shoot girth (cm)</th>
<th>Leaf length (cm)</th>
<th>Leaf number</th>
<th>Bulb length (cm)</th>
<th>Bulb number</th>
<th>Bulb girth (cm)</th>
<th>Bulb number/plant</th>
<th>Fresh yield weight/bulb (g)</th>
<th>Fresh yield of blackgram (g pot⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1 -Control</td>
<td>18.4</td>
<td>7.7</td>
<td>17.9</td>
<td>10.5</td>
<td>3.1</td>
<td>6.1</td>
<td>2.9</td>
<td>33.9</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>T-2 -RP-S³G @ 15 kg P₂O₅ ha⁻¹</td>
<td>19.4</td>
<td>9.6</td>
<td>24.8</td>
<td>13.8</td>
<td>3.2</td>
<td>6.8</td>
<td>4.6</td>
<td>43.8</td>
<td>215</td>
<td></td>
</tr>
<tr>
<td>T-3 -RP-S³G @ 30 kg P₂O₅ ha⁻¹</td>
<td>24.7</td>
<td>12.0</td>
<td>25.5</td>
<td>16.8</td>
<td>3.8</td>
<td>7.5</td>
<td>5.1</td>
<td>54.9</td>
<td>236</td>
<td></td>
</tr>
<tr>
<td>T-4 -RP-S³G @ 45 kg P₂O₅ ha⁻¹</td>
<td>28.1</td>
<td>13.3</td>
<td>29.6</td>
<td>17.3</td>
<td>4.1</td>
<td>7.4</td>
<td>5.4</td>
<td>55.5</td>
<td>252</td>
<td></td>
</tr>
<tr>
<td>T-5 -RP-S³G @ 60 kg P₂O₅ ha⁻¹</td>
<td>34.7</td>
<td>13.7</td>
<td>32.3</td>
<td>21.8</td>
<td>4.6</td>
<td>8.1</td>
<td>5.9</td>
<td>59.6</td>
<td>282</td>
<td></td>
</tr>
<tr>
<td>T-6 -RP-S³G @ 75 kg P₂O₅ ha⁻¹</td>
<td>32.5</td>
<td>12.9</td>
<td>28.2</td>
<td>19.8</td>
<td>4.3</td>
<td>7.7</td>
<td>5.8</td>
<td>57.0</td>
<td>275</td>
<td></td>
</tr>
<tr>
<td>S.E.(d)</td>
<td>1.1</td>
<td>0.56</td>
<td>1.1</td>
<td>1.2</td>
<td>0.18</td>
<td>0.18</td>
<td>0.13</td>
<td>1.67</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>C.D. (0.05)</td>
<td>2.2</td>
<td>1.2</td>
<td>2.3</td>
<td>2.5</td>
<td>0.38</td>
<td>0.38</td>
<td>0.26</td>
<td>3.56</td>
<td>18.4</td>
<td></td>
</tr>
</tbody>
</table>
ment and improving protein content of seed (Singaram and Kothandaraman, 1993).

### Table 4. Residual effect of different levels of RP-S/G on yield attributes and yield of blackgram (var CO.5) (Mean)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Pod length (cm)</th>
<th>Pod weight/pot (g)</th>
<th>Pods/ plant</th>
<th>Seeds/ pod</th>
<th>100 grain weight (g)</th>
<th>Root length (cm)</th>
<th>Root weight/pot (g)</th>
<th>Grain yield (g pot⁻¹)</th>
<th>Stover yield (g pot⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1 -Control</td>
<td>4.9</td>
<td>14.0</td>
<td>12.0</td>
<td>5.8</td>
<td>2.1</td>
<td>10.1</td>
<td>0.40</td>
<td>8.2</td>
<td>11.7</td>
</tr>
<tr>
<td>T-2 -RP-S/G @ 15 kg P₂O₅ ha⁻¹</td>
<td>5.0</td>
<td>15.9</td>
<td>16.8</td>
<td>6.5</td>
<td>2.3</td>
<td>11.4</td>
<td>0.43</td>
<td>9.2</td>
<td>12.8</td>
</tr>
<tr>
<td>T-3 -RP-S/G @ 30 kg P₂O₅ ha⁻¹</td>
<td>5.3</td>
<td>16.4</td>
<td>14.0</td>
<td>7.0</td>
<td>2.5</td>
<td>12.5</td>
<td>0.45</td>
<td>9.6</td>
<td>13.0</td>
</tr>
<tr>
<td>T-4 -RP-S/G @ 45 kg P₂O₅ ha⁻¹</td>
<td>5.5</td>
<td>16.7</td>
<td>22.8</td>
<td>7.5</td>
<td>3.0</td>
<td>13.4</td>
<td>0.48</td>
<td>10.0</td>
<td>12.9</td>
</tr>
<tr>
<td>T-5 -RP-S/G @ 60 kg P₂O₅ ha⁻¹</td>
<td>5.9</td>
<td>16.8</td>
<td>30.5</td>
<td>8.5</td>
<td>3.3</td>
<td>14.0</td>
<td>0.51</td>
<td>10.6</td>
<td>13.2</td>
</tr>
<tr>
<td>T-6 -RP-S/G @ 75 kg P₂O₅ ha⁻¹</td>
<td>6.3</td>
<td>17.3</td>
<td>28.5</td>
<td>8.3</td>
<td>3.2</td>
<td>14.3</td>
<td>0.53</td>
<td>10.5</td>
<td>13.0</td>
</tr>
<tr>
<td>S.E(d)</td>
<td>0.22</td>
<td>0.32</td>
<td>1.61</td>
<td>0.30</td>
<td>0.22</td>
<td>0.30</td>
<td>0.02</td>
<td>0.11</td>
<td>0.30</td>
</tr>
<tr>
<td>C.D (0.05)</td>
<td>0.47</td>
<td>0.67</td>
<td>3.44</td>
<td>0.63</td>
<td>0.46</td>
<td>0.64</td>
<td>0.04</td>
<td>0.23</td>
<td>0.63</td>
</tr>
</tbody>
</table>

**Residual effect on pH and availability of nutrients:** Different levels of RP-S⁰ granule had little residual effect on soil pH at harvest stage of blackgram (Table-5). The acidity produced due to S⁰ oxidation might have been used for the RP dissolution and neutralized by calcium released during RP dissolution. This was in line with the findings of Bhosale (1987).

### Table 5. Residual effect of different levels of RP-S/G on pH and available nutrients (mg kg⁻¹) in soil at post harvest stage of blackgram (var CO.5)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>pH</th>
<th>Available N (mg kg⁻¹)</th>
<th>Available P (mg kg⁻¹)</th>
<th>Available K (mg kg⁻¹)</th>
<th>NaCl TEA-P (mg kg⁻¹)</th>
<th>NaOH TEA-P (mg kg⁻¹)</th>
<th>NaOH Pi (mg kg⁻¹)</th>
<th>NaOH Po (mg kg⁻¹)</th>
<th>HCl Residual P (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1 -Control</td>
<td>7.55</td>
<td>53.2</td>
<td>3.13</td>
<td>201.3</td>
<td>8.00</td>
<td>5.0</td>
<td>57.5</td>
<td>10.6</td>
<td>80.0</td>
</tr>
<tr>
<td>T-2 -RP-S/G @ 15 kg P₂O₅ ha⁻¹</td>
<td>7.53</td>
<td>55.3</td>
<td>5.50</td>
<td>206.8</td>
<td>12.02</td>
<td>7.8</td>
<td>62.5</td>
<td>18.1</td>
<td>88.0</td>
</tr>
<tr>
<td>T-3 -RP-S/G @ 30 kg P₂O₅ ha⁻¹</td>
<td>7.43</td>
<td>56.7</td>
<td>5.75</td>
<td>209.5</td>
<td>15.78</td>
<td>7.5</td>
<td>68.0</td>
<td>20.0</td>
<td>166.0</td>
</tr>
<tr>
<td>T-4 -RP-S/G @ 45 kg P₂O₅ ha⁻¹</td>
<td>7.45</td>
<td>58.8</td>
<td>7.00</td>
<td>209.5</td>
<td>19.25</td>
<td>8.0</td>
<td>70.5</td>
<td>22.5</td>
<td>158.0</td>
</tr>
<tr>
<td>T-5 -RP-S/G @ 60 kg P₂O₅ ha⁻¹</td>
<td>7.50</td>
<td>60.2</td>
<td>9.13</td>
<td>212.0</td>
<td>22.20</td>
<td>7.5</td>
<td>74.0</td>
<td>25.0</td>
<td>162.0</td>
</tr>
<tr>
<td>T-6 -RP-S/G @ 75 kg P₂O₅ ha⁻¹</td>
<td>7.48</td>
<td>59.5</td>
<td>8.25</td>
<td>210.8</td>
<td>24.93</td>
<td>8.8</td>
<td>78.0</td>
<td>14.4</td>
<td>170.0</td>
</tr>
<tr>
<td>S.E(d)</td>
<td>0.28</td>
<td>0.17</td>
<td>0.51</td>
<td>0.61</td>
<td>0.58</td>
<td>1.70</td>
<td>4.0</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>C.D (0.05)</td>
<td>0.62</td>
<td>0.34</td>
<td>NS</td>
<td>1.08</td>
<td>1.31</td>
<td>12.43</td>
<td>3.61</td>
<td>8.6</td>
<td>2.7</td>
</tr>
</tbody>
</table>

The higher available N registered by RP-S⁰ granule (60.2 mg kg⁻¹) might be due to the fact that, the combination of RP and S⁰ made P more available in soils and this increasing nodule formation and nitrogen fixation in leguminous crops (Manjaiah et al., 1995). The nodule numbers and microbial populations recorded in the present study further confirmed the results. Increase in the levels of P had a remarkable residual effect on available P up to 60 kg P₂O₅ ha⁻¹ (9.13 mg kg⁻¹) and slightly decreased at 75 kg P₂O₅ ha⁻¹ (8.25 mg kg⁻¹). It may be due to the acid produced during the oxidation of S⁰ which enhanced the availability of P in soil (Rajan, 1982).

The residual effect was not significant for soil available K. The different levels of RP-S⁰ granules had significant residual effect on S content of soil. The S released during oxidation of S⁰ and the mineralisation of native P could be attributed to increased concentration of S at post harvest stage (Rajan, 1983).

**Residual effect on P-fractions (Table 5):** Marked increase in the concentration of NaCl TEA-P and NaOH-Pi (solution+adsorbed P) was observed. Any increase in NaOH extractable P is likely to provide an estimate of P dissolved from RP. However, a significant decrease in NaOH-Po was observed due to either the dissolved P was immobilized or part of the NaOH-
Po was chemically admitted with soil particles strongly (Bolan and Hedley, 1989). The decrease in HCl-P and residual P further confirmed the dissolution of soluble P caused by lowered pH in soil under blackgram, and subsequent uptake by crop.

To conclude, addition of RP-S^0 granule at 60 kg P_2O_5 ha^{-1} recorded the highest yields of onion and blackgram, nutrient availability in soil and also the P fractions.

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**REFERENCES**