Effect of rock phosphate and superphosphate fertilizer on the productivity of maize var. Bisma

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Abstract
Superphosphate (SP) fertilizers have been used widely to improved food crop production in Indonesia. However, the high cost of SP is now focusing attention on rock phosphate (RP) fertilizer as a natural phosphorus (P) source and because of its relatively low cost. A field experiment was conducted to evaluate the effects of RP and SP-36 fertilizers and interaction between treatments on the productivity of maize on a Latosolic soil (low available Bray-II extractable P). A split-plot design with three blocks as replicates was used, with sources of P fertilizer as main plots and four levels of P fertilizer as subplots. Results showed that RP and SP-36 fertilizers increased maize grain yield, dry matter (DM) stover yield, and crude protein (CP) contents of maize stover over those of the control that did not receive P fertilizer. Superphosphate-36 application resulted in higher maize grain yield, DM yield, and CP contents of maize stover than crops treated with RP fertilizer at the same rate. The highest P-use efficiency for grain and stover was obtained with RP and SP-36 fertilizers that provided 66 kg P ha⁻¹.

Introduction
In Indonesia corn or maize (Zea mays L) is an important crop as a source of food and livestock feed. Maize stover is used as ruminant livestock feed. However, most of the land in Indonesia used for food crops production has non-productive Latosolic soils characterized by low phosphorus (P) and low pH.

An insufficiency of P in the medium from which the crop draws its mineral nutrition results in retarded growth, reduced development, vegetative mishaps and, often severely reduced grain yield. In cereals the problems associated with P deficiency mainly appear during the active growth stages that are most demanding of this element. Phosphorus deficiency can be corrected by applying P fertilizer to the soil at or before sowing (Grundon, 1987). According to Coates et al. (1990), the application of P fertilizer during periods of active growth increased forage crop yield and quality. The extent to which added P fertilizer increases the supply of P to plants growing in a specific soil depends on the type of fertilizer and the characteristics of that soil (Helyar and Godden, 1976).

Superphosphate fertilizers have been widely used to improve food crop production on non-productive land in Indonesia. However, the high cost of SP is now focusing attention on RP fertilizer. Rock phosphate is a natural P sources, it is relatively cheaper than SP, and it is locally available. There are RP deposits in Cirebon (West Java), and in Gresik (East Java). According to Kerridge and Ratcliff (1982), RP can also be used as a maintenance fertilizer for pasture species on acid soils in humid areas.

Rock phosphate contains P in a form that is not readily soluble in water but soluble in neutral ammonium citrate solution making it slowly available to plants. Water-insoluble P-fertilizers do not all behave in the same way as SP. Finely ground RP is an apatite mineral and when added to acid soils, the solubilization of RP is increased so that below pH 5.5 it begins to make a significant contribution, and on really acid soils it can be a useful source of phosphate. The agronomic effectiveness of RP depends on the chemical and mineralogical nature of the rock, the pH, and other characteristics of the soil, and the crop (Young et al., 1985).
Table 1. Maize var. Bisma grain yield, and P-use efficiency with rock phosphate (RP) and SP-36 fertilizers

<table>
<thead>
<tr>
<th>Level of P fertilizer (kg P ha⁻¹)</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>P-use efficiency (kg grain kg⁻¹ P)</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>P-use efficiency (kg grain kg⁻¹ P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4028 d</td>
<td>0</td>
<td>4085 d</td>
<td>0</td>
</tr>
<tr>
<td>66</td>
<td>5199 c</td>
<td>79</td>
<td>6285 b</td>
<td>95</td>
</tr>
<tr>
<td>132</td>
<td>5885 bc</td>
<td>44</td>
<td>7342 a</td>
<td>55</td>
</tr>
<tr>
<td>198</td>
<td>6257 bc</td>
<td>31</td>
<td>7599 a</td>
<td>38</td>
</tr>
</tbody>
</table>

Mean followed by the same letters are not significantly different at DMRT 5%.

Superphosphate-36 contains 36% P₂O₅, with the P in a water-soluble form. Water-soluble phosphate when added to acid soils will be precipitated as iron (Fe) or aluminium (Al) phosphates and tends to be tightly absorbed by mineral colloids in the soil. Soils with strong adsorption properties, such as acid clays, will often need very high rates of added phosphate to significantly raise their phosphate-supplying power. Both types of P fertilizer (RP and SP) are directly applied to the soil (Young et al., 1985).

The objective of the reported research was to study the effect of RP and SP-36 fertilizers and the interaction between treatments on the maize productivity in Latosolic soil.

Materials and methods

A field experiment of split-plot design with three block as replicates was conducted during 3 months on three blocks of Latosolic soil with the following pH values: 4.73 (block I), 4.48 (block II), and 4.26 (block III). Available P (Bray-II extractable) was 2.59 (block I), 2.15 (block II), and 1.72 ppm (block III). Soil nitrogen (N) contents (%) were: 0.029 (block I), 0.020 (block II) and 0.019 (block III). Thus, the soil was acid, low in P and of low-medium N content. The experiment was conducted on 240 m² divided into 24 plots. Each plot size was 3.5x2.5 m, or 8.75 m². Four levels of P fertilizer from two sources were established as treatments.

The main plot consisted of P fertilizers from two sources; RP containing 27% P₂O₅, and SP-36 containing 36% P₂O₅. Four levels of P fertilizer (0, 66, 132 and 198 kg P ha⁻¹) were used as sub-plots. Standard fertilizers, i.e., urea (46% N) at 100 kg N ha⁻¹, and KCl (60% K₂O) at 83 kg K ha⁻¹, were applied to each plot.

Maize seed var. Bisma was dibbled into small holes made with a wooden stick at the rate of two seeds per hole, spaced 70x40 cm. Each plot contained 60 plants or 68571 plants ha⁻¹. Fertilizer-P (RP and SP-36) and KCl were dibbled close to planting holes at sowing. Shallow sub-surface banding (5 cm beside and below the seeds) can significantly increase P fertilizer use efficiency over broadcast fertilizer application (Randall and Hoeft, 1988). One-third of the urea was applied at the time of germination a week after sowing. The remaining two-thirds of the urea was applied at the time of flowering, or at 4 weeks after sowing dibbled close to the maize plants.

The maize was harvested 3 months after sowing and the grain sun-dried for 3 days. After harvesting the maize grain, the stover was cut close to the ground and measured for dry matter (DM) yield and crude protein (CP) content (N content in % x 6.25) Each replicate was the average measurement from four plants/two holes. To measure DM yield (DM content in % x fresh stover yield) the harvested stover material (leaves and stalk) was chopped, sub-sampled, and oven-dried to constant weight at 70 °C for 48 h. These samples were finely ground and analyzed for N content by Kjeldahl digestion and titration (Islam et al., 1992). The N content of maize stover was assessed as the total leaf and stalk N, and as DM yield.

The analyses of variance on grain yield, DM yield, and CP content were made using the general linear model procedure of SAS. Significant differences among the treatments were calculation using Duncan's Multiple Range Test (DMRT).

Results

The application of RP and SP-36 fertilizers resulted in the production of maize grain yields (Table 1), and DM yields of maize stover (Table 2) significantly