Improvement of suboptimal soil productivity to growth and production of groundnut (*Arachis hypogea* L.)

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Abstract. Increasing suboptimal soil productivity in agricultural land to increase food production needs to be encouraged. A proper land management design is necessary to overcome the various obstacles and problems faced to increase suboptimal soil productivity. The purpose of this research, which was conducted at ex rice field of suboptimal soil, was to improve suboptimal soil productivity for plantation peasants by developing soil management recommendations, mainly through a combination of inputs needed to optimize the growth and productivity of potato plants based on soil conditions. A combination of lime dosage and organic matter (Petroganic) dosage with basic fertilizer (urea, N-P-K, and dolomite) were applied by using a Randomized Completely Design (RCD) for 8 (eight) treatments with three replication. The results showed that P4, treatment with the highest lime dosage, and Petroganic produced the highest fresh groundnut pod. It can increase production as high as 89% as compared to control. All treatment combinations of lime and Petroganic increased fresh nut pod between 46% to 89% compared to control. The use of basic fertilizer only increases production by 32% as compared to control. To achieve higher fresh nut pod yield, watering or irrigation should be included in soil management.

1. Introduction

Groundnut (*Arachis hypogea* L.) is a type of legume that is an important vegetable protein source for Indonesian people. Groundnut is consumed in raw and processed form. Groundnut is commonly cultivated on dry land with average national productivity of 1,373 ton/ha in 2018 [1]. Since consumption need is still greater than the national production rate, it is estimated that there will still be a big deficit per year, so Indonesia still needs to import from other countries [2]. Based on projections, groundnuts' production in 2018 was 468.08 thousand tons [2] with large consumption of 722.26 thousand tons, which comes from direct consumption, seeds, scattered, and processed [3].

The increase in groundnut production is influenced by soil, water, climate, fertilizers, and farmers' habits. Acid soils dominate soils in Indonesia, so the majority of them are classified as suboptimal soils. As much as 82% of the total dry land area in Indonesia is classified as suboptimal land. It is necessary to give certain additional treatments so that the soil can be optimized in supporting plant growth. The general treatment given to soil is providing additional input in fertilizers, organic and inorganic, and agriculture lime. The application of organic matter can be in the form of manure, improving soil
characteristics both chemically, physically, and biologically. Based on [4], organic matter provision can help supply N, P, and K elements for plants, impacting the provision of basic fertilizer (N, P, K).

Suboptimal soils in Indonesia are generally characterized by low productivity, generally characterized by acidic soil reaction internal factors with a pH range of 5.5 or less, so as a recommendation, it is necessary to add lime into the soil management recommendation package. Soils that have an acidic soil reaction face low nutrient availability constraints and face the threat of negative effects from high aluminum levels, which are toxic and inhibit plant growth can even cause plant death. Therefore, it is also necessary to apply agricultural lime and dolomite to increase the availability of essential nutrients for plants, increase soil pH, increase the availability of calcium and magnesium elements, and reduce or eliminate aluminum risk poisoning in plants. The characteristic of external factors is the threat of drought in the dry season. Thus, it is necessary to include irrigation or irrigation factors in the soil management package to ensure the crops' water supply.

In general, suboptimal soils also contain low carbon or organic matter. Whereas organic matter has several important functions, especially: 1) one of the most important soil components for the soil ecosystem, 2) a source of binding nutrients and substrates for soil microbes, and 3) important ingredients for increasing soil fertility, both physically and chemically and biological. Thus, efforts to increase and maintain the organic matter content to maintain tropical soil productivity need to be done [5, 6]. Sources of organic matter are the remains of plants and animals that are constantly changing due to physical, chemical, and biological processes. The main organic matter components are carbohydrates, crude protein, cellulose, hemicellulose, lignin, and fat. The application of organic fertilizers to the soil can improve soil structure and promote micro-population of soil organisms. The physical function of organic matter is to increase granulation, reduce plasticity and increase the holding capacity of groundwater [7]. Soil physical properties greatly affect plant growth and production [8].

Suboptimal soil is soil that naturally has low productivity due to internal and external factors. The use of suboptimal land needs to be increased for agricultural development through increased productivity. To improve soil and plant productivity in sub-optimal soils, fertilizers and soil enhancers are importantly required. Fertilizers are various forms of materials that contain nutrients that can be used to supply plant shortages or needs. Meanwhile, soil amenders are synthetic or natural, organic or mineral materials in the form of solid and liquid, improving the physical, chemical, and biological properties of the soil. Based on the constituent compounds, soil repairers are divided into inorganic, organic, and biological materials. The fertilizer differentiator and the soil repairer are given in large quantities, while the soil repairer is given in small amounts. Soil enhancers aim to improve soil conditions, releasing nutrients bound to other compounds so that they are not available to plants, improving the soil's ability to absorb water (hydrophilic) or repel water (hydrophobic). Soil repairers alone cannot replace the amount of various nutrients that come out of the soil due to harvest, erosion, and other losses, so they still have to be supplied by additional nutrients obtained from fertilizers.

According to [9], to overcome the main obstacles faced with increasing dryland productivity is done by applying lime and phosphate. This effort has increased dryland productivity, which is reflected in the increased yield of food crops. Intensive use of lime and phosphate on dry land causes an increase in soil pH, which results in decreased positive charge and Al ion deposition [9].

The low productivity of groundnuts may be caused by several factors, such as low-quality seeds, degraded land due to the high use of chemicals in pesticides and fertilizers used in cultivation practices in the field. The application of artificial fertilizers is still carried out conventionally without considering the need and availability of nutrients in the soil. Plant pests' control is carried out using a calendar system without being based on agro-ecosystems observations in the field. The use of pesticides, both dosage and type, is not yet following the target that disturbs the crop.

Groundnut productivity in dryland is still low in the range of 0.6 - 1.2 ton/ha, while in paddy fields, it is around 1.2-1.8 ton/ha. One of the causes of the low productivity of groundnuts is that fertilizers have not been used appropriately and efficiently [10]. Fertilization and lime application are important things that must be considered in increasing groundnut production. [11] stated that groundnuts need sufficient amounts of N, P, K, and Ca, which can be fulfilled through fertilization and lime application.
Organic matter and dolomite can replace excessive chemical fertilizers and provide maximum growth and yield in groundnut plants.

In an effort to increase the production of groundnuts (*Arachis hypogea* L.), there are several influencing factors. One of the factors is soil suitable for its growth. According to [12], the soil is an important environmental factor with a reciprocal relationship with the plants that grow on it. Productive soil must be able to provide a good environment such as air and water for plant root growth, as well as being able to provide nutrients. These environmental factors involve various soil properties, such as water availability, temperature, aeration, and good soil structure [7, 12].

Until now, development by planting groundnuts has also been found in former rice fields. Paddy soil is defined as land cultivated for a long time (hundreds of years) and shows a distinctive profile, which deviates from the original soil. Deviations include forming a plow layer that is almost impermeable to water, called padasolah, 10-15 cm deep from the ground and 2-5 cm thick. There is generally a layer of manganese and iron under the plow layer, and the thickness varies depending on the soil's permeability. This layer can be a solid layer that does not penetrate the roots, especially for seasonal plants. The paddy soil is generally acidic with low nutrient content, one of which is calcium. It is because plants constantly absorb the nutrient calcium without fertilizing with calcium. One of the efforts to improve acid soil in paddy soil is liming. Liming can increase the calcium base and soil pH from the hydrolysis of the weak acids which are part of the compound [12].

The purpose of this study was to improve suboptimal soil productivity for groundnut plantation by developing soil management recommendations, mainly through a combination of inputs needed to optimize the growth and productivity of potato plants based on soil conditions.

2. Methodology

2.1. Location and period of research

The research was conducted from early July to the first week of November 2020. The demonstration plot research was carried out in farmers' land, classified as suboptimal soil on an area of approximately 1000 m² in Cimaung Village, Cikeusal District, Serang Regency, Banten Province, Indonesia.

2.2. Design and composition of treatment

The selection and setting of treatment were determined by considering the results of soil conditions evaluation. Basically, for food crops such as groundnut, that kind of suboptimal soil like in the study area still requires agricultural lime and organic matter. The combination of these two elements was formulated into eight treatments, including one control treatment. Except for control, the seven treatments were given basic fertilizer, which consisted of urea, N-P-K (15-15-15), and dolomite. This research used a Completely Random Design with eight treatments and 3 (three) replications, so the total research plots were 24 units. Each plot's size was 5 m × 6 m, so each plot area was 30 m². The distance planting was 25 cm × 40 cm. Details of the eight treatments are presented in Table 1. Each treatment had 3 (three) replications with an area of 30 m²/plot.

| Treatment Symbol | Lime Dosage | Petroganik Dosage | Basic Fertilizer | Treatment  |
|------------------|-------------|-------------------|-----------------|-----------|
| P1               | Dose 1      | Dose 1            | Urea, N-P-K, dolomite | K1P1+   |
| P2               | Dose 2      | Dose 1            | Urea, N-P-K, dolomite | K2P1+   |
| P3               | Dose 1      | Dose 2            | Urea, N-P-K, dolomite | K1P2+   |
| P4               | Dose 2      | Dose 2            | Urea, N-P-K, dolomite | K2P2+   |
| P5               | Dose 1      | Dose 0            | Urea, N-P-K, dolomite | K1P0+   |
2.3. Soil sampling, field observation, and laboratory analysis

Evaluation of soil conditions was carried out through field observations and soil analysis in the laboratory. Field observations were made by observing and measuring the effective soil depth and soil drainage. Soil sampling consists of composite soil samples for laboratory analysis of soil chemical properties and soil texture. Sample for (core sample) is taken to determine the bulk density of the soil. Laboratory analysis of soil chemical properties consists of pH, organic carbon content, total N, available P, exchangeable K, Ca and Mg, cation exchange capacity, and aluminium saturation.

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2.3.3. Demonstration plot. The land used for groundnut research had long been cultivated in the past. Soil cultivation, planting, and plant maintenance until harvesting were carried out on plots according to the treatment design. The area of each plot is 30 m$^2$. There were 45 plots in total from 10 treatments with three replications. A variety of KP-01 with a rather long harvest life (120 days) was applied. Plant observations were carried out by measuring plant height during the vegetative period and the number of pods and fresh pod weight for the generative aspect.

2.3.4. Laboratory analysis. Data analysis was used Microsoft Excel 2019. The data obtained from each plot and replicates were analyzed with variance at the α 5% level of confidence and further tested using the Duncan Multiple Range Test (DMRT) at α 5% level to determine the differences between treatments.

3. Results and discussion

3.1. Evaluation soil condition

The soil used in the demonstration plots is suboptimal and has not supported the high groundnut production target. The soil preliminary evaluation results indicated that the soil has medium physical support, except for the soil bulk density, classified as relatively high dense. Its soil chemical properties can be classified as rather poor, accompanied by several main soil parameters that can inhibit plant growth and production. The soil has very acidic soil reaction (very low soil pH); low total N and exchangeable K; very low total organic carbon and available P; and medium exchangeable Ca and Mg. Descriptions of the chemical and physical properties of soil at the demonstration plots are presented in
Increasing soil productivity requires applying organic matter or organic fertilizer and agricultural lime to improve the soil not to have an acidic soil reaction.

**Table 2.** The characteristic of the main soil properties.

| No | Parameters                          | Unit | Number | Category |
|----|------------------------------------|------|--------|----------|
| 1  | Soil acidity (pH)                  |      | 4.72   | Acid     |
| 2  | Organic carbon (C-Org)             | %    | 0.33   | Very low |
| 3  | Total nitrogen (N-Total)           | %    | 0.13   | Low      |
| 4  | Phosphor (P) – available           | Ppm  | 1.91   | Very low |
| 5  | Calcium (Ca) – exchangeable        | cmol+/kg | 4.07 | Moderate |
| 6  | Magnesium (Mg) interchangeable     | cmol+/kg | 1.52 | Moderate |
| 7  | Potassium (K) – exchangeable       | cmol+/kg | 0.11 | Low      |
| 8  | Cation exchangeable capacity (KTK) | cmol+/kg | 17.46 | Moderate |
| 9  | Aluminium - saturation             | %    | 1.32   | Very low |
| 10 | Texture                            |      |        | Loam     |
| 11 | Effective depth                    | Cm   | 94     | Deep     |
| 12 | Drainage                           |      |        | Good     |
| 13 | Soil bulk density                  | g/cc | 1.31   | Slightly dense |
| 14 | Permeability                       | cm/hour | 15.42 | Slightly fast |

3.2. Effect of treatment on growth and production of groundnut

When viewed from the production of groundnut pods, the highest weight of fresh pods was produced from P4, a combination of lime application dose 2 (1,500 kg/ha) and dose two petrogenic (2,000 kg/ha), which production reached 4,000 ton/ha, followed by P3, a combination of lime application dose 1 (500 kg/ha) and dose 2 Petroganik (2,000 kg/ha) with a production of 3,478 tons/ha, and P2, a combination of lime application dose 2 (1,500 kg/ha) and manure dose 1 (1,000 kg/ha). The production of fresh groundnut pod from each treatment in full can be seen in table 3 and figure 1.

**Table 3.** Effects of treatment on plant height, number of pods, and weight of fresh groundnut pods.

| Symbol of treatment | Treatment | Height of plant (cm) | Number of pod per plant | Weight of fresh pod |
|---------------------|-----------|----------------------|-------------------------|---------------------|
|                     |           | 20 days 60 days      |                         | g/plant* kg/plot ton/ha |
| P1                  | K1P1++    | 8.14 ab 25.13 a      | 21                      | 45.67 a 9.4 3,122 ab |
| P2                  | K2P1++    | 8.22 a 25.48 a       | 19                      | 40.17 a 10.0 3,344 ab |
| P3                  | K1P2++    | 8.23 a 25.06 a       | 16                      | 38.37 a 10.4 3,478 ab |
| P4                  | K2P2++    | 7.83 ab 26.21 a      | 23a                     | 49.83 a 12.0 4,000 a |
| P5                  | K1P0++    | 7.53 ab 24.86 a      | 20                      | 45.43 a 9.3 3,089 ab |
| P6                  | K2P0++    | 7.21 b 23.80 a       | 22                      | 44.63 a 10.0 3,333 ab |
| P7                  | K0P0++    | 7.79 ab 25.53 a      | 24                      | 46.30 a 8.3 2,778 ab |
| P8                  | Control   | 7.75 ab 23.11 a      | 16                      | 27.77 a 6.3 2,111 b |

Remark: the numbers followed by the same letter and in the same column are not significantly different according to the Duncan Multiple Range Test at a 5% confidence level.
Figure 1. Illustration of comparison of treatment effects on fresh groundnut pod weight was the most excellent treatment effect to increase pod production two times compared to control.

There is a difference in correlation between plant heights and fresh pod weight at different plant ages. Plant height at 20 days of age has a low correlation, shown by the correlation coefficient (R) of 0.15 to the weight of fresh pods. However, a high correlation occurred when the plants were 60 days, when there was a period of flowering and pod filling, with the correlation coefficient (R) reaching 0.70. Therefore, only plant height at 60 days of age can indicate the weight of fresh pods. There was no high enough correlation between the number of pods and the weight of fresh pods, where the correlation coefficient (R) was only 0.35. It shows that the weight of fresh groundnut pods is more determined by the beans’ density and weight that fill the pods, not just the number of pods. The elemental largely determines the size, density, and weight of beans in groundnut pods Ca content. Other researchers stated that P's elemental content also had a significant role in relation to the production of groundnut beans. Soil N content controls more vegetative growth.

Compared with the control, the percent increase in the production of fresh groundnut pods from each treatment can be seen in table 4. P4 resulted in the largest increase 89%, so that the ratio of increase in fresh pod weight to control reached 1.89. The next highest increase was achieved by P3, who received an increase of 65%, P2 58%. All of them would be a combination of lime application and Petroganik organic matter if given lime alone at a dose of 1,500 kg/ha (P6), the production of fresh pods increased by 58% compared to the control. Meanwhile, if only basic fertilizer is provided (Urea 100 kg/ha, N-P-K 500 kg/ha, and dolomite 500 kg/ha), then the production of fresh pods will increase 32% (see table 4).

Table 4. Ratio and percentage of potato tuber weight production increase for each treatment to control.

| Treatment                | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
|--------------------------|----|----|----|----|----|----|----|----|
| Production (ton/ha)      | 3.12 | 3.34 | 3.48 | 4.00 | 3.09 | 3.33 | 2.78 | 2.11 |
| The ratio of tuber       | 1.48 | 1.58 | 1.65 | 1.89 | 1.46 | 1.58 | 1.32 | 1.00 |
| production to control    |    |    |    |    |    |    |    |    |
| Production increased     | 48 | 58 | 65 | 89 | 46 | 58 | 32 | 0  |
| over control (%)         |    |    |    |    |    |    |    |    |

The increase of the fresh pod nut weight by the combination of lime and Petroganik was expected previously. Liming application can increase soil pH to improve soil reaction. It can increase the
availability of soil nutrients, especially N, P, K, Ca, and Mg, and control the negative effects of microelements such as Fe and Mn under acidic condition. The increase in soil fertility and soil productivity with the application of Petroganik can be explained by an additional supply of essential soil nutrients (macro and microelements), increasing the activity of soil organisms, and improving the soil physical properties, especially those related to improving available water for plants and maintaining a good gas supply needed by plants via good soil aeration.

Research by [9] showed that application of lime as much as 1.0 Al-dd could increase pod yield and dry groundnut beans as a result of the role of lime in improving soil properties. Improvements in soil properties include increasing pH, base saturation, exchangeable Ca, S, and P availability, and reducing aluminium saturation. The results of soil analysis after harvest showed an increase in pH from 4.52 to 5.08; Ca content from 1.93 to 4.90 me/100g; S and P-available respectively from 20.36 to 27.34 ppm and from 2.90 to 3.12 ppm; base saturation from 25.40 to 55.60%; and reducing the Al saturation from 43.80 to 15.20%. The activity of soil microorganisms also increases with the improvement of the chemical properties of the soil. [13] also reported that applying lime to dry acid soils increased the filled pods of groundnuts from 60.3% to 67.3%. This is thought to be because giving lime significantly increases amino acids (methionine, cystine, and cysteine) in groundnut beans. As well as an increase in pods and dry groundnut beans, an increase in amino acid levels occurs due to lime's role in improving soil chemical properties such as increasing pH, Ca, S, and P levels alkaline saturation and reducing soil aluminium saturation.

The application of lime and sulfur was also hypothesized to improve the quality of groundnut beans. During the study, the bean quality was monitored by analyzing the levels of amino acids, namely methionine, cistin, and cysteine. The application of lime and sulfur improves groundnut beans' quality, reflected in the significantly increased methionine, cistin, and cysteine levels. The lime application significantly increased levels of amino acids (methionine, cistin, and cysteine) of groundnut beans, respectively, from 0.56-0.75 ppm, 0.58-0.70 ppm, and from 0.39-0.54. ppm. As well as an increase in pods and dry groundnut beans, an increase in amino acid content occurs due to lime's role in improving soil chemical properties such as increasing pH, Ca, S, and P levels alkaline saturation and reducing soil aluminium saturation. Application of lime 1.0 Al-dd significantly increased the dry groundnut beans from 864 to 1,058 kg/ha [9].

The results of this study are also supported by research conducted by [14] and [15], which showed that manure could provide macronutrients (nitrogen, phosphorus, potassium, calcium, and sulfur) and micronutrients (iron, zinc, boron, etc. cobalt, and molybdenum). The biological function of organic matter is as a source of energy and food for soil microorganisms to increase the activity of soil microorganisms that are very useful in supplying plant nutrients. Thus the application of organic fertilizers will ultimately increase plant growth and production [16]. Likewise, [17] research results, where the dosing of organic matter bokashi 20 tons/ha can significantly increase the pod weight per plant. According to [18], applying organic fertilizers to support growth in groundnut plants. According to [19] stated, the increase in plant height was influenced by organic matter, which provided nutrition for groundnut plants. Besides, giving organic fertilizers also increases the microbial population in the soil. The microbes in the soil fertilize the soil and provide nutrients that plants readily absorb. According to [20], indirectly, microbes in the soil helped absorb nutrients in groundnut plants to increase their growth.

The application of dolomite and organic fertilizers (fine compost) had no significant effect on pod weight per plot of groundnut plants. There was an interaction between organic fertilizer and dolomite fertilizer, which have no significant impact on pod weight per plot of groundnut plants. It is assumed that water availability has decreased due to decreased rain intensity, reducing the yield of groundnuts. At the pod formation and bean filling stage, groundnut plants require adequate water. Groundnuts planted in the dry season often experience drought. Limited water availability during the generative phase can inhibit pod formation and bean filling [21]. The nutrient P also greatly affected the yield components of groundnuts. Element P had a significant effect on the weight of dry pods. It occurred because the P nutrient tends to influence the yield component [22, 23].
Due to the less loose soil conditions and the lack of water availability that affected pod formation. Groundnuts require loose soil and sufficient water availability at the time of pod formation. In limited water conditions, it could reduce the number of pods per plant [24]. Groundnut plants form pods in the root area (rhizosphere) at a depth of 5-15 cm from the soil surface. Thus, the loose structure in the root area is the main key in pod formation. The hard soil surface will prevent the groundnut gynophores from penetrating deeper into the soil, thus inhibiting pod development [25]. Nutrient P is needed in groundnut plants for pod formation. Groundnut plants needed the P element because this P element could activate pod formation, fill in empty pods, and speed up fruit ripening [26]. Giving dolomite, which contains Ca elements, was important in the formation of gynophores; thus, gynophores' addition affected the number of pods formed [27].

Drought attacks encountered, particularly during the last two weeks of September 2020 and first of October 2020 when the plant was approaching and in the flowering period and the early pod nut formation period, results in not achieving the expected fresh pod nut production target, which was around 5 ton/ha since a superior yielding variety was applied. Groundnut plants, which initially showed excellent growth, experienced setbacks and even mild stress due to drought. Manual watering efforts could not be done since there were no available sources of water as the source of watering of the land-farm to overcome the plant stress due to drought problem and meet the water needs for plants. Groundnuts require loose soil and sufficient water availability at the time of pod formation. The soil in the research location was classified as dense with a bulk density of 1.31 g/cc. By experiencing drought during pod formation, it will cause obstacles and disruption in the pod formation process. Limited or dry water conditions could reduce the number of pods per plant [24] and the filling of bean or bean seed in the pods. Loose soil structure and sufficient water in the root area are the main keys in pod formation and filling.

3.3. Soil management development for suboptimal soil improvement
Suboptimal soils such as those in the study site were characterized by acidic soil conditions and low bases and organic matter content, and the threat of drought during the dry season. In this study, the land management design based on soil conditions has shown expectations as targeted. The combination of lime and Petroganic at the beginning of the growing period has shown the expected results. From the production of groundnut pods, it could also be seen that the effect of the combined treatment of lime at a dose of 1,500 kg/ha and 2,000 kg/ha of Petroganic could increase the highest production by 89%. Even if there had been no onset of drought during the last two weeks of September 2020, the effect of increasing production would have been even greater. However, the attack of drought, which has caused the drying up of water sources that can usually be relied on as water supply for irrigation, can be seen to affect inhibiting growth. Moreover, the soil used in this study was formerly paddy soil so that it did not have loose soil. Even the bulk density was quite high (1.31 g/cc). In a state of water shortage or drought, the soil in the root zone was not in a loose condition, even hardens, so that it greatly impedes the formation and filling of groundnut pods.

From experience drawn from this research, the development design of appropriate soil management can significantly increase the growth and production of groundnut pods. In this study, the combination of giving lime with doses ranging from 500 kg/ha to 1,500 kg/ha and Petroganik manure at doses of 1,000 kg/ha to 2,000 kg/ha for the first planting season has shown an increase in soil productivity in the research location which can be classified as in the suboptimal soil group. However, drought in suboptimal soils also needs to be included in the soil management package to achieve the highest productivity gains.

4. Conclusion
Soil management has been designed to increase the growth and production of groundnuts on suboptimal soils at the study site through a combination design of lime application at a dose of 500 to 1,500 kg/ha and Petroganik at a dose of 1,000 kg/ha to 2,000 ton/ha and basic fertilizers (100 kg of urea, 500 kg of NPK fertilizer, and 500 kg of dolomite) had significantly increased the production of fresh groundnut
 pods by up to 89%. Failure to achieve increased production is caused by drought, which causes the plants to experience stress ahead of and the initial period of pod formation and filling. In order to achieve higher production increases, the soil management package needs to be supported by irrigation schemes to prevent crops from drought stress. The availability of air strongly influences groundnut pod production during the pod formation and filling of the beans.

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