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Research Article
Effect of Arbuscular Mycorrhizal and Sago Dregs on Peanut Plants (*Arachis hypogaea* L.) Grown on Southeast Sulawesi's Dryland

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Abstract

Background and Objective: Cultivation of peanut crop in Southeast Sulawesi is generally carried out on dryland. It is one of the main causes of the plant low productivity. Dryland has poor physical, chemical and biological properties and has thus limited support to plant growth. The use of sago dregs is one alternative as a source of organic fertilizer for the crop. In addition, arbuscular mycorrhizal fungi can be used to increase crop production. Therefore, this study purposed to study the effectiveness of sago dregs and arbuscular mycorrhizal fungi in increasing the growth and yield of peanut crop. **Materials and Methods:** This study used a randomized block design (RBD) in a split plot pattern. The main factors were 4 levels of inoculum of arbuscular mycorrhizal fungi, i.e., 0 (M0), 20 g (M1), 40 g (M2) and 60 g (M3)/planting hole. Sub factors consisted of 4 levels of sago dregs, namely 0 (P0), 5 t ha^{-1} (P1), 10 t ha^{-1} (P2) and 15 t ha^{-1} (P3). Variables observed were plant growth, root colonization and P uptake. **Results:** The effect of arbuscular mycorrhizal inoculation in single or its interaction with sago dregs fertilizer did not significantly affect the entire observation parameters. In contrast, sago dreg fertilizer had a significant effect on all parameters observed, except on plant height and number of branches at 14 days after planting and the number of empty pods. **Conclusion:** The effectiveness of sago dregs and arbuscular mycorrhizal fertilizer was indicated by increased peanut growth, phosphorus absorption and root colonization. The best treatment was obtained by using 15 t sago dregs ha^{-1}.

Key words: Peanut plant growth, phosphorus absorption, root colonization, arbuscular mycorrhizal fungi, sago dregs

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is one of the crops whose yields are consumed by many people. Apart from being consumed directly, peanut seeds are also used as industrial raw materials in production of, such as, butter, cooking oil and various juices. Peanut seeds contain 23.68% protein, 49.66% fat, 21.51% carbohydrate[1] and vitamin B1. The high nutrient contents of peanut seeds lead to increased public interest in consuming peanut seeds which results in a continuous increase in demand for peanut seeds. Because of the low productivity of this crop in Southeast Sulawesi, the demand for peanut seeds cannot be met.

The low productivity of peanut crop in Southeast Sulawesi is particularly caused by a poor fertility of its soils, which are dominated by dryland. The dryland in Southeast Sulawesi covers about 60.3% of the province's total area, whose soils belong to order Ultisols and Oxisols[2]. Dryland has so poor physical, chemical and biological properties that it is unable to support optimal plant growth[3]. One means of increasing sustainable crop production is the use of organic fertilizers. The use of organic fertilizers can reduce the use of inorganic fertilizers to improve plant growth[4]. Organic fertilizers can improve soil physical, chemical and biological properties and are economically much more affordable than inorganic fertilizers and can reduce the cost of agricultural production.

The use of organic fertilizer is very important in crop cultivation system in Southeast Sulawesi. Sago dregs are widely spread in Southeast Sulawesi and can be a potential organic fertilizer in crop cultivation. Sago dregs contains a high amount of nutrients essential for plants[5]. It was reported that sago dregs contained 23.1% organic-C, 1.73% nitrogen, 1.3% phosphorus and 1.5% potassium[6]. Sago dregs have been tested and proven to increase the growth of various types of plants, such as, corn[7] and soybean[8]. In addition to sago dregs, arbuscular mycorrhiza can be used to increase peanut yields. Arbuscular mycorrhiza (AM) is a type of fungi symbiotic with plant roots and both benefits each other. Arbuscular mycorrhizal associations with plants can directly increase plant growth and productivity[9]. The presence of AM can increase the availability of nutrients, especially phosphate[10], water uptake[11], soil nutrient status and uptake in corn[12-14], growth and yield of corn[15-18] and Pelargonium (*Pelargonium zonale* L.)[19]. The current study was, therefore, carried out to study the effects of sago dregs and arbuscular mycorrhiza on the growth and yield of peanut crops grown on a dryland region of Southeast Sulawesi.

MATERIALS AND METHODS

Research design: This study was conducted at the Field Laboratory and Agrotechnology Laboratory of the Agricultural Faculty, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia, 2018. This study used a randomized block design (RBD) in a split plot pattern. The main factors consisted of 4 levels of arbuscular mycorrhizal fungi, i.e., 0 (M0), 20 g (M1), 40 g (M2) and 60 g (M3)/planting hole, whereas the sub factors consisted of 4 levels of sago dregs, i.e., 0 (P0), 5 t ha^{-1} (P1), 10 t ha^{-1} (P2) and 15 t ha^{-1} (P3). Parameters observed were peanut crop growth, root colonization and P uptake.

Materials and tools: The materials used throughout the study were peanut seeds, sago dregs, bran of rice, lime, granulated sugar, tarps, arbuscular mycorrhizal inoculum, aquades, 10% KOH solution, 2% HCl, 10% H_2O_2 and blue aniline 0.05%. The tools used were hoes, machetes, scopes, measuring tapes, scales, ovens, scissors, petri dishes, measuring cups, object glasses and microscopes, Erlenmeyer, multilevel filters with pore sizes of 355, 125 and 15 µm, beaker, micro pipette, drop pipette, camera and stationeries.

Application of sago dregs: The sago dregs used were firstly fermented for one month and then incorporated into the soil one week before planting. The amount of sago dregs applied per plot was based on the corresponding treatment described in the experimental design.

Planting and arbuscular mycorrhiza inoculation: The inoculum of arbuscular mycorrhiza was collected from rhizosphere of blady grass (*Imperata cylindrica*) with spore population densities of ±500/100 g soil. The inoculum was incorporated into each planting hole before the seeds were sown. The plant spacing used was 75 cm×20 cm, with one seed/planting hole.

Observation of arbuscular mycorrhiza: Spores of arbuscular mycorrhiza were extracted from soil by wet sieving and decanting method[20]. Infected roots were observed based on the slide method[21]. Root infections were calculated according to the following equation:

$$\text{Root infection (\%)} = \frac{\text{Number of infected roots}}{\text{Number of observed roots}} \times 100$$

Evaluation of growth dan yield of peanut crops: The crop growth was evaluated at 14 and 28 day after planting (dap). Variables observed were plant height (cm, measured from crop stem base to the tip of the stem), diameter of stem (cm, measured at stem middle point using the sliding term), number of leaves (by counting all fully expanded leaves):

$$\text{Leaf area (cm}^2\text{)} = L \times W \times C$$

where, L is leaf length, W is leaf width and C is the constant), dry weight of crop biomass (dried in oven at 80°C for 2×24 h), yield of the crops and P uptake (at 30 dap).

Statistical analysis: Statistical analysis was performed using two-way analysis of variance (ANOVA) and further tests with Duncan multiple range test (DMRT) at $\alpha = 0.05$.

RESULTS

Analysis of soil biological and chemical properties and sago dreg nutrient content: The results of the laboratory analysis of soil biological and chemical properties show that the soil nutrient contents in the study site fell under ranking very low (Table 1), while the sago dregs contained a high amount of nitrogen, phosphorus, potassium, calcium and magnesium (Table 2).

Effect of arbuscular mycorrhizae and sago dregs on peanut plants: The peanut vegetatif growth observed were plant height, number of leaves, number of branches, leave area index, dry-weight biomass and relative growth rate, while its generative growth observed were total number of pods, number of filled pods, number of empty pods, pod weight, weight of 100 seeds and the crop productivity. No interaction effect between arbuscular mycorrhiza and sago dregs was found and no main affect of arbuscular mycorrhiza was found either. Sago dregs, however, showed a significant effect on all parameters observed, except plant height and number of branches at 14 DAP, flowering age and the number of empty pods (Table 3). Further tests with DMRT ($p<0.05$) indicated a significant increase in growth and yield of the crop in response to sago dregs fertilization at 10 t ha^{-1}. However, no significant difference in the growth of plants treated with sago dregs fertilization at 10 and 15 t ha^{-1}, except for the total number

Table 1: Soil biological and chemical properties in the study site

Variable of analysis	Value	Rank
Organic matter (%)	0.33	Very low
Organic-C (%)	0.19	Very low
N-total (%)	0.02	Very low
C/N ratio	10.15	Low
Phosphorus (mg/100 g)	0.48	Very low
Potassium (mg/100 g)	0.01	Very low
Calcium (cmol(+)/kg)	0.08	Very low
Mg (cmol(+)/kg)	0.31	Very low
Base saturation (cmol(+)/kg)	23.05	Low
CEC (cmol(+)/kg)	1.82	Very low
Na (cmol(+)/kg)	0.02	Very low
pH	3.58	Very acidic

Table 2: Nutrient contents of sago dregs

Nutrient contents of sago dregs	Value
Nitrogen (%)	13.55
Phosphor (mg/100 g)	29.55
Potassium (mg/100 g)	5.10
Calcium (cmol (+)/kg)	10.97
Mg (cmol (+)/kg)	1.97

Table 3: Recapitulation of analysis variance of growth and yield of peanut crop treated with arbuscular mycorrhiza and sago dregs fertilizer

Observation variable	Day after planting	Arbuscular mycorrhiza (M)	Sago dregs fertilizer (P)	M×P
Plant height	14	ns	ns	ns
	28	ns	**	ns
Number of leaves	14	ns	**	ns
	28	ns	**	ns
Number of branches	14	ns	**	ns
	28	ns	**	ns
Leaf area index	14	ns	*	ns
	28	ns	**	ns
Biomass	14	ns	ns	ns
	28	ns	**	ns
Relative growth rate		ns	**	ns
Flowering age		ns	ns	ns
Total number of pods		ns	**	ns
Number of filled pods		ns	**	ns
Number of empty pods		ns	ns	ns
Pod weight		ns	**	ns
Weight of 100 seeds		ns	*	ns
Productivity		ns	**	ns

ns: Not significantly different, *Significantly different, **Very significantly different

Table 4: Peanut plant growth and yield by using treatment of arbuscular mycorrhiza and sago dregs fertilizer

Observation variables	Days after planting	Sago dregs (t ha^{-1}) 0 (P0)	5 (P1)	10 (P2)	15 (P3)
Plant height	28	7.37^{b}	8.14^{b}	9.88^{a}	10.56^{a}
Number of leaves	14	8.06^{b}	8.89^{a}	9.13^{a}	9.36^{a}
	28	18.15^{c}	20.89^{b}	23.45^{a}	24.39^{a}
Number of branches	14	2.17^{b}	2.31^{b}	2.69^{a}	2.82^{a}
	28	3.79^{c}	4.07^{bc}	4.58^{ab}	4.74^{a}
Leaf area index	14	0.12^{b}	0.35^{ab}	0.14^{a}	0.15^{a}
	28	0.22^{c}	0.30^{b}	0.39^{a}	0.41^{a}
Biomass (g)	28	3.09^{c}	3.62^{bc}	4.18^{ab}	4.57^{a}
Relative growth rate (g g^{-1}/day)		1.10^{b}	1.27^{ab}	1.42^{a}	1.49^{a}
Total number of pods		14.56^{d}	24.18^{c}	29.12^{b}	32.11^{a}
Number of filled pods		12.95^{d}	20.94^{c}	25.00^{b}	28.39^{a}
Pod weight (g)		14.01^{c}	21.62^{b}	26.91^{a}	29.36^{a}
Weight of 100 seeds (g)		40.30^{b}	41.82^{ab}	42.74^{a}	44.11^{a}
Productivity (t ha^{-1})		1.01^{c}	1.57^{b}	1.96^{a}	2.15^{a}

Values in the same row followed by different letters indicate a significant difference according to Duncan multiple range test (DMRT) at $\alpha = 0.05$

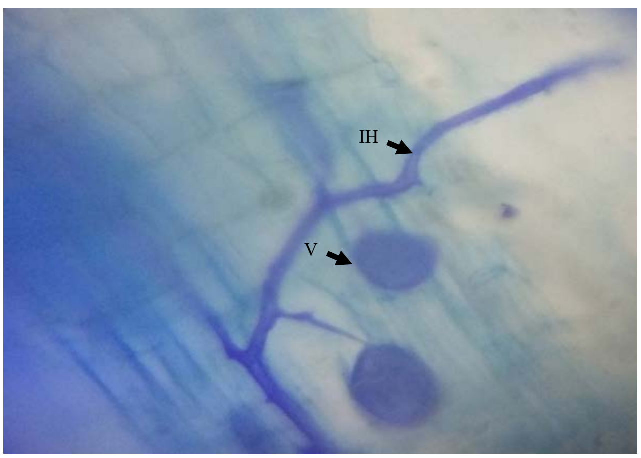

Fig. 1: Microscopic appearance of a peanut plant root colonized by arbuscular mycorrhizae
IH: Internal hyphae, V: Vesicles, Magnification: 40×10

of pods and number of filled pods. The productivity of the crop treated with 15 t sago dregs ha^{-1} reached 2.15 t peanut seeds ha^{-1} (Table 4). Even though the analysis of variance indicated that the inoculation of arbuscular mycorrhizal showed no significant effect (neither main nor interaction effect) on all crop growth and yield parameters, it appears, based on the results of microscopic observations (Fig. 1), that the arbuscular mycorrhiza has colonized roots of the host plant (peanut crop), as indicated by the presence of internal hyphae and the formation of vesicles within the host plant root cells. In addition, plants inoculated with arbuscular mycorrhizae generally had a higher phosphorus uptake than those not inoculated. The highest P absorption was 10.86 mg by crops treated with 60 g arbuscular mychorrizal inoculum per planting hole and 15 t sago dregs ha^{-1} (Fig. 2).

DISCUSSION

Findings of this study show that sago dregs had the potential to increase the growth and productivity of peanut plant grown on dryland in Southeast Sulawesi. This is indicated by a significant increase in the growth and productivity of plants treated with sago dregs, compared to untreated plants (Table 4). Increased productivity reached 112% in plants treated with 15 t ha^{-1} sago dregs compared to untreated plants. This study also found arbuscular mycorrhizae association with host plant as indicated by arbuscular mycorrhizae-colonized roots (Fig. 1). This association helps the host plants increase their phosphorus uptake, as indicated by the higher phosphorus contents in plants inoculated with the AM fungi compared to those uninoculated (Fig. 2).

The result of soil analysis shows that the soil in the study area had very low soil biological and chemical properties (Table 1). The low organic matter and available plant nutrient contents caused the plant growth below optimal threshold. These conditions require technological inputs, in the form of, among others, sago dregs fertilizer and arbuscular mycorrhiza to increase plant growth and productivity. The provision of technological input in form of sago dregs fertilizer to plants inoculated with arbuscular mycorrhizae can increase plant yields. The sago dregs fertilizer increases the plant yield components, e.g. the number of total pods, number of filled pods, seed weight, pod weight, seed weight and plant productivity. The best amount of sago dregs fertilizer applied was 15 t ha^{-1} (Table 4). Furthermore, the average plant P uptake increased with application of sago dregs fertilizer (Fig. 2). Sago dregs fertilizer contains enough nutrients to support plant growth. The chemical analysis shows that the sago dregs used in the study contained a high amount of

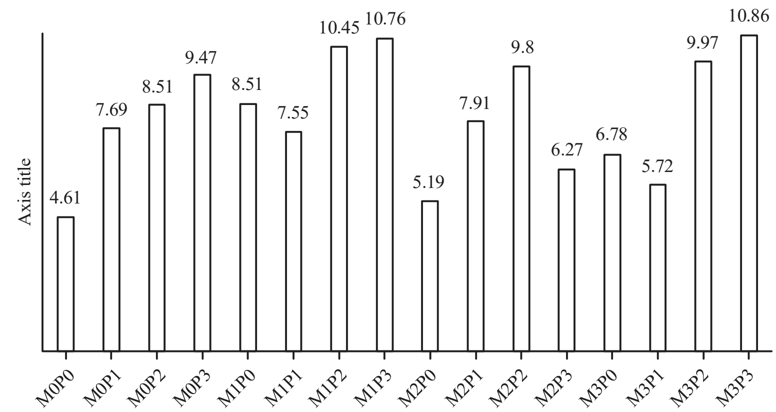

Fig. 2: Phosphorus uptake (mg) of peanut plants treated with sago dregs and arbuscular mycorrhizal
P0-P3: 0, 5, 10 and 15 t ha^{-1} of sago dregs, M0-M3: 0, 20, 40 and 60 g of arbuscular mycorrhiza inoculum/planting hole

macro nutrients, such as N (13.55%), P (29.55%), K (5.10%), Ca (10.97%) and Mg (1.97%) (Table 2). Macro nutrients, which are required in large quantities, are the building blocks of crucial cellular components, such as proteins and nucleic acids. Nitrogen, phosphorus, magnesium and potassium are some of the most important macronutrients. They help increase the yield, growth and quality of various crops[22]. Crops use more N than any other mineral nutrient, nearly all plant N is found in the proteins, total N removal by crops relates to the amount of material removed and the protein concentration of the harvested material[23].

Nitrogen is an essential constituent of chlorophylls, which are closely associated with photosynthetic process. Total chlorophyll, chlorophyll a, chlorophyll b and chlorophyll a/b ratios of *Vigna unguiculata* and *Vigna radiata* were significantly affected by fertilizer application over time[24]. Phosphorus is critical to root growth and function and the proper cycling of energy in the plant. Phosphorus deficiency symptoms affect older leaves first which may be small and bluish green on the margins. Other symptoms might include: reduced flowering, decrease in fruit quality and delayed fruit maturity[25]. Potassium role is linked to many physiological processes which help improve photosynthesis, enzyme activation, water relations, assimilates, transportation, as well as plant growth and development[26]. Magnesium plays a major role in plant photosynthesis and thus its deficiency degrades ability of plant growth[27].

The presence of inherent arbuscular mycorrhizal fungi in the study area is a limitation for obtaining significant results related to the effects of arbuscular mycorrhizal inoculation, even though the soil had been sterilized. However, this limitation is a suggestion to further research in managing soils containing arbuscular mycorrhizal fungi naturally using various treatments of organic matters.

CONCLUSION

The effectiveness of sago dregs fertilizer and arbuscular mycorrhiza indicated with increasing growth, phosphorus uptake and root inspected of peanut plants by arbuscula mycorrhiza. The best treatment was obtained by using 15 t ha^{-1} of sago dregs.

SIGNIFICANCE STATEMENT

This study assessed the use of sago dregs for fertilization on dry land with very low nutrient content and their potential benefits for peanut plants in increasing the plant biomass and productivity. This manuscript presents new findings regarding the high potential of sago dregs as a source of organic fertilizers on low nutrient containing dryland, which have not been reported so far. This study may help researchers to uncover the use of marginal land for higher productivity of peanut cultivation that has not been explored by many researchers. Subsequently, a new theory on how sago dregs affect this crop development grown in nutrient-poor environments may be postulated.

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