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Increasing the Fertility and Productivity of Marginal Land by Planting Leguminous Plants

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ABSTRACT

Background: Marginal land is dry land which has limited nutrient content so it has relatively low productivity. The development of marginal land use can be optimized with an ecosystem approach strategy through improving soil fertility. Planting leguminous plant species that can fix nitrogen from the atmosphere can increase soil fertility.

Methods: This research was conducted to determine the ability of plants (A = Corn; B = Peanuts; C = Green Beans; D = Soybeans) to increase soil fertility and plant productivity. The experiment was designed in a randomized block design consisting of four treatments, each treatment was repeated four times. Soil fertility analysis was carried out before planting (pH, Carbon (%), Nitogen (%) and C/N) and after planting [pH, Carbon (%), Nitogen (%) and C/N]. Productivity [straw (kg/ha), seeds (kg/ha] and effective nodules.

Result: The experimental results showed that the planting of legumes had a significant effect on increasing soil fertility and forage productivity, nodulation but lower legume seed production compared to maize.

Key words: Corn, Legumes, Marginal land, Production, Soil fertility.

INTRODUCTION

Most of the land in the tropics is marginal land with low to very low crop production potential. In South Sulawesi, the marginal area reaches 449,606 ha which are spread over several districts (BPS, 2018). Suboptimal pH conditions, insufficient water availability and steep terrain make marginal areas a major challenge for sustainable biomass production without large investments (Milbrandt and Overend, 2009). To be optimal, marginal land must be managed properly, if land) (Csikos and Toth, 2023). Due to its potential to increase food security and support the production of bioenergy or ecosystem services, as well as its great potential as a renewable resource, it has received a lot of attention worldwide (Csikos and Toth, 2023).

Different external inputs are required to realize the potential of marginal land. Nitrogen has become an integral part of food and feed production systems. The use of nitrogen fertilizers in agriculture, which are important for high-yielding varieties, has shifted in parallel since the management is not appropriate it can degrade primary land and become marginal (unproductive Green Revolution (Pani *et al.*, 2021). The application of nitrogen fertilizers has increased crop yields and led to self-sufficiency in food production in many developing countries (Sainju *et al.*, 2018). Excessive use of nitrogen (N), insufficient groundwater and high carbon emissions threaten sustainability (Lamptey *et al.*, 2018). Ironically, the application rate of nitrogen fertilizers in agriculture is higher among small and marginal farmers. In addition, the economic and ecological production costs are higher than the profits from farming (Pani *et al.*, 2021). Long-term application of ammonia-based nitrogen fertilizers such as urea has increased soil acidity, resulting in soil infertility where plants do not respond to further applications of nitrogen fertilizers (Sainju *et al.*, 2018). The use of energy-dense synthetic fertilizers should be reduced, preferably through closed nutrients in the biomass production cycle (Nobel *et al.*, 2016).

Increasing the productivity of marginal land can be done by utilizing marginal agricultural land with low input systems (Cossel, 2019). Soil protection can be done by planting legumes (Koukolicek *et al.*, 2018). Legumes play a very important role in intensive cropping systems to reduce nitrogen uptake and increase soil fertility by providing nitrogen to host plants and other plants through a process known as biological nitrogen fixation (BNF) (Kebede, 2021, Meena and Kumar, 2022). Nitrogen (N) fixed by legumes can provide 20-60 kg of N for later components and plants in the system (Lalotra *et al.*, 2022). The ability of legumes to fix nitrogen from the atmosphere and produce biomass and fix carbon (C) is an important factor in reducing greenhouse gas emissions. Therefore, legumes are considered as a solution to reduce nitrogen oxide (N2O) emissions (Jangir *et al.*, 2022). The use of legumes as an

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integral part of agricultural practices due to their role in improving soil nitrogen status and forage quality has received increasing attention in meeting the demand for food and animal feed production (Kebede, 2021).

In mitigation studies on marginal plots, legumes appear to be a good choice for increasing soil fertility, forage production and quality, because legumes can meet their nitrogen requirements through atmospheric nitrogen fixation by rhizobia bacteria in their root nodules (Akca *et al*., 2022). As well as increasing soil fertility, legumes have been an important source of nutrients in food and feed for thousands of years. Their history as part of a traditional diet dates back to their agricultural origins, when their contribution to soil health and agricultural productivity began to be recognized by farmers, mostly empirically (Ferreira *et al*., 2021). Therefore the purpose of this study was to determine the ability of legumes (peanuts, mung beans, soybeans) and corn to increase soil fertility, production and quality of forage.

MATERIALS AND METHODS

Experiment conditions

The effect of planting maize and legumes (peanuts, mung beans and soybeans) on soil fertility, straw production and quality was tested in a marginal plot in Pattonon Salu Village, Maiwa District, Enrekang Regency, located at 3°46′04.9″S 119°52′00.5″E, located at an altitude of 50-100 m above sea level with a flat topography, tropical climate (average annual temperature 25°C-27°C) with an average rainfall of 1500 mm. The experimental soil is sandy loam. Prior to the experiment, soil chemical analysis was carried out (Table 1). Each treatment plot used a 5 × 5 m plot (25 m^2/trial unit). Each experimental plot consisted of 5 rows of plants, the distance between rows was 100 cm and each row was sown with 10 seeds with a spacing of 50 cm, so that there were 50 plant populations in each plot.

Experimental design

A randomized block design was used in this study, which consisted of four treatments: maize, peanuts, green beans and soybeans and each treatment consisted of four replicates. Each treatment plot used a 5 × 5 m plot (25 m^2/ trial unit). Each experimental plot consisted of 5 rows of plants, the distance between rows was 100 cm and 10 seeds were sown in each row with a spacing of 50 cm, so that there were 50 plant populations in each plot. Seeds were planted on June 25, 2022 and planted until they bear fruit. During maintenance, weed control was carried out and water was given to each plot as needed. Harvested the plants on September 18, 2022 after the plants were physiologically ripe. All crops (maize, peanuts, mung beans and soybeans) were harvested by hand from each plot. The roots were rinsed thoroughly and the remaining water was absorbed with absorbent paper, then the nodules were separated from the roots and collected, the pink nodules showing high efficiency in N fixation were considered as efficient nodules. The yield of plant seeds was obtained by separating the corn kernels from the cobs, while the legume seeds are separated from the pods, then dried in the sun until they reached a moisture content of around 14%, then weighed and converted to kg/ha. Production of straw (stems and leaves) of corn and legumes from each treatment unit was weighed to determine fresh weight production. Weigh 1 kg of straw and then dry it in an oven at 65°C for 72 hours until it reaches a constant dry weight.

Statistic analysis

Experimental data were analyzed statistically by ANOVA using SPSS software. A one-way analysis of variance procedure was used to test the effects of the different treatments. Duncan's real range test was used to determine different treatments ($P \leq 0.05$).

RESULTS AND DISCUSSION

Soil fertility arameters

Soil pH

The acidity (pH) of the soil planted with corn was not different from that planted with peanuts, green beans and soybeans. The results of soil analysis before planting corn, peanuts, green beans and soybeans had an average pH of 5.90 (slightly acidic). After planting corn and peanuts, green beans and soybeans, the soil pH increased to pH > 6. According to the analysis by the Etiosis team (2014), the increase in pH occurred from 5.6-6.5 (slightly acidic) to 6.6-7, 3. (neutral). Based on USDA criteria (2001), soil pH ranges from (5.5-8.5).

Carbon (C)

The marginal soil carbon (C) content is strongly influenced by the type of plant. Soil planted with peanuts contained significantly higher carbon than soil planted with corn, but there was no difference in the carbon content of the soil planted with peanuts, green beans and soybeans (Table 1). The results of this study indicate that legumes have a higher capacity for storing soil organic carbon than maize plants. In Table 1, it appears that there is an increase in the carbon content of the soil after planting corn, peanuts, green beans and soybeans.

Legumes increased the organic carbon content in the soil significantly after harvest compared to the initial state (Hajduk *et al*., 2015). According to Kumar *et al.* (2018) that legumes have the ability to store soil organic carbon by 30% higher than other species; this is due to their ability to fix nitrogen. Rodriguez *et al.* (2022) found that the influence of legumes on prairie soil organic carbon varied with the proportion of legumes consistently across broad spatial scales. Soil organic carbon increased with legume proportion to 7-17%, then decreased.

Nitrogen (N)

The nitrogen content of the soil planted with maize was significantly lower than that of the soil planted with peanuts, mung beans and soybeans, but there was no difference in the nitrogen content of the soils planted with peanuts, mung beans and soybeans. The increase in nitrogen content in the plots planted with legumes was due to the ability of legumes to fix nitrogen from the atmosphere. According to Kebede (2021), legumes can increase soil fertility through a symbiotic relationship with microorganisms such as rhizobia which fix them (Kebede, 2021). In peanuts, the amount of fixed nitrogen exceeds the amount of nitrogen contained in economic yields (Toomsan *et al*., 2012).

C/N

Carbon (C) and Nitrogen (N) in the soil are the main components of organic matter known as soil fertility (Swangjang, 2015). The ratio of carbon and nitrogen shows the degradation rate of organic matter which is the main source of carbon in soil. A high C:N ratio indicates the presence of relatively large amounts of weathered soil materials. The C:N ratio of soil planted with corn is much higher than in soil already planted with peanuts, mung beans and soybeans. According to USDA (2011) that legume soils have a low C:N ratio, while soils that have been planted with corn have a high C:N ratio. The carbon to nitrogen ratio indicates the rate of material degradation, while the C:N ratio values smaller means organic matter is more easily decomposed.

Production

Corn straw

Actual straw production ($P<0.05$) was affected by crop type (Table 2). Straw production from peanut, green bean and soybean straw was higher than corn straw. Production of peanut straw was significantly ($P<0.05$) higher than green bean production and highly significant ($P<0.01$) compared to soybeans. The average production of corn straw, peanuts, mung beans and soybeans in this study was lower than reported by other researchers. Modesto *et al*., (2021) reported that corn straw production varied between 4106 kg/ha to 9478 kg/ha depending on the season. For peanuts, the production of fresh straw reached 3.72 t/ha (Gomonet and Cagasan, 2020), mung bean straw 1906 kg/ha (Ahmad *et al*., 2003) and soybean straw 1853 kg/ha (Quddus *et al*., 2020). The low production of crop straw obtained from marginal land is due to the low soil nutrient content (Table 1).

Seed production

Maize production was not different from peanut production but significantly ($P<0.05$) higher than green beans and very significantly ($P<0.05$) higher than soybean production. Production of corn, peanuts, green beans and soybeans on this marginal land is very low compared to some researchers. Ardie *et al.* (2021) reported that maize production in Indonesia fluctuated between 1.21-6.13 t/ha. Peanut production ranges from 0.96-1.6 t/ha (Lubis *et al*., 2012), green beans ranges from 584-588 kg/ha (Kumar *et al*., 2018) and soybeans ranges from 1.91-3.17 t/ha (Borowska and Prusiñski, 2021).

Effective nodule

To determine the effectiveness of root nodule, the first symptom that can be seen is the color of the inside of the nodule becomes orange or reddish (due to leghemoglobin), which indicates that the nodule is effective. Table 2 shows that the number of effective nodules on peanut plants was significantly (<0.05) higher than that of mung bean and soybean nodules, while the effective nodule on mung bean did not differ from the active nodules on soybeans. According to Flynn and Idow (2015), effective nodules are those that are pink or red. According to Rejili *et al*. (2012) the diversity and efficiency of nitrogen-fixing legumes is very important for the dynamics of soil fertility in arid areas.

Table 1: Soil chemical analysis before planting and after harvesting of maize and peanut, green bean and soybean crops.

Parameters	Before planting	After planting			
		A	B	C	D
pH	5.90	6.02±0.24[a]	6.14±0.24[a]	6.17±0.22[a]	6.30±0.10[a]
Carbon (%)	1.61	1.72±0.05[b]	1.98±0.18[a]	1.81±0.14 [ab]	1.83±0.09 [ab]
Nitrogen (%)	0.12	0.12±0.00[b]	0.18±0.03[a]	0.15±0.01[a]	0.15±0.02[a]
C/N	13.00	14.11±0.91[a]	11.18±1.94[b]	11.85±0.53[b]	12.30±1.23[b]

Means ± standard error followed by the same letters are not significantly different at $P>0.05$.

Table 2: Effect of plant types on forage production.

Parameters	Plant type			
	A	B	C	D
Straw production (kg/ha)	976.75±16.37[d]	1884.40±17.66[a]	1682.00±18.97[b]	1195.40±13.52[c]
Seed production (kg/ha)	386.00±22.03[a]	366.65±16.88[a]	320.00±24.43[b]	178.15±9.92c
Effective nodule count/plant	0.00±0.0[c]	62.00±5.94[a]	51.75±8.42[b]	51.25±3.77[b]

Means ± standard error followed by the same letters are not significantly different at $P>0.05$.

CONCLUSION

Planting corn, peanuts, green beans and soybeans on marginal land increases soil fertility compared to the pre-planting period. Legumes peanuts, green beans and soybeans provide better soil fertility improvements than maize because of their ability to fix nitrogen from the atmosphere. The effect of planting corn and peanuts, mung beans and soybeans on the production of straw as an effective source of animal feed, seed yield and root nodules shows that these three legumes (peanuts, mung beans and soybeans) have advantages over maize.

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Conflict of interest: None.

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