Improving the quality of acid soils to increase soybean yields and farmer’s incomes

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Abstract. Lampung Province has a great potency for increasing national soybean production, although most of the area is occupied by the acid dry land soils. The aims of the study were to determine the effect of three different packages of soybean cultivation technology on soybean growth and yield, the cropping index, and the farmers’ income on an acid dry land soil of East Lampung. The experiments tested three packages of soybean cultivation technology, namely Local Farmer Technology, Site Specific Technology, and Recommended Technology. The treatments were arranged in a Randomized Block Design with 10 replications. The results showed that soybean yield of the Site Specific Technology was 1.33 t ha⁻¹, which was significantly higher than that of the Local Farmer Technology, with a yield of 0.78 t ha⁻¹. Meanwhile, the yield of the Recommended Technology was 1.26 t ha⁻¹, which was not significantly different from the yield of the Site Specific Technology. There was an increase in soybean yield and income by 66 and 30% with the application of the Site Specific Technology compared with the application of the Local Farmer Technology. Therefore, the Site Specific Technology might be recommended for increasing soybean production, especially in Lampung.

1. Introduction

The potential for acid dry land in Lampung Province is 2,650,413 ha and suitable for food crops covering an area of 912,609 ha [1], therefore the contribution of Lampung Province is large enough to increase soybean production in acid dry land. Currently the use of acid dry land for soybean cultivation still quite low due to many obstacles in managing the land. Public consumption reaches 2.5 million tonnes of dry soybeans per year, consisting of direct consumption of 2 million tonnes of population, 3,000 tonnes of animal feed, 39,000 tonnes of seeds, 446,000 tonnes of non-food industry, and 49,000 tonnes of milk [2].

The strategy to increase national soybean production can also be pursued through a program to expand the planting or harvest area and increase productivity to support soybean self-sufficiency program. The expansion of the soybean harvested area is considered capable of contributing significantly to the increase in national soybean production [3]. The harvested area for soybeans, which has only reached about 600 thousand ha with a productivity of 1.57 t ha⁻¹, must be expanded to reach 1.5 million ha with a productivity target of 1.70 t ha⁻¹. Soybean development in sub-optimal lands, such as acid dry land, can be used to increase production and land productivity in a sustainable manner. Currently, soybean productivity in Lampung is classified as low, namely 1.16 t ha⁻¹. Meanwhile, soybean productivity at the national level has reached 1.50 t ha⁻¹.
Technical constraints faced in developing soybeans on acid dry land are low soil pH (<5.0) which was associated with high Al content, and P fixation, low exchangeable base content and CEC, iron and manganese contents reaching toxic limits, poor trace elements, and limited biotic and water. This condition was not suitable for soybean development, so to grow optimally and provide maximum results, it requires relatively high input of ameliorant in the form of lime and organic matter and NPK inorganic fertilizer.

Liming is important for increasing soil fertility, especially soils with low pH, because lime that is given to the soil can bind toxic elements such as Al and Fe, so that the soil pH increases and P and K elements become available to plants. To make acid dry land as a source of optimal agricultural production growth requires technological innovation and dissemination of research results in a balanced manner [4].

The use of superior varieties of soybeans that are adaptive and high production in acid dry land needs to be studied, as an effort to increase production in order to support national soybean self-sufficiency. The used of natural phosphate rock as an ameliorant or as a source of phosphate fertilizer is rarely used by farmers [5]. Apart from managing P nutrient on acid dry land, liming and organic matter application also need to be done.

The purpose of utilization of local organic waste or local organic fertilizers available in the location is intended to improve soil fertility and quality, and soil physical and chemical properties. Improvement of soybean cultivation on acid dry land by utilizing local agro-industrial waste and rock phosphate is to reduce the use of chemical fertilizers, so that the efficiency of soybean farming on acid dry land is more profitable. The research objective was to improve the quality of acid dry soil and increase the income of food crop farmers on acid dry land and increase the cropping index.

2. Materials and methods

2.1. Materials
The activity was carried out in Margototo Village, Metro Kibang Subdistrict, East Lampung Regency. In acid dry land agroecosystems with a soil pH of 4.23 (very acidic). The materials used were soybean seeds Demas-1 variety and local varieties, dolomite, cow manure compost, biochar from corn cobs waste, agrisoy bio-fertilizer, NPK fertilizer, liquid smoke, and chemical pesticides.

2.2. Methods
The experiments tested three packages of soybean cultivation technology, namely Local Farmer Technology (A), Site Specific Technology (B), and Recommended Technology (C). The treatments were arranged in a Randomized Block Design with ten replicates. The parameters measured in the study were growth and yield components, and farmers’ socio-economic. The data were calculated using the analysis of variance (ANOVA) and means were compared by the Least Significant Difference (LSD) test (P <0.05). Farmer’s socio-economic data were analysed with the MBCR test. The stages of activities carried out include determining the location of research and prospective farmer co-operators, farmer and land characteristics (physical, chemical and composite soil sampling), local organic fertilizer inventory, baseline surveys and socialization of activities, preparation of facilities and infrastructure, assessment, land preparation (experimental plotting, planting, and fertilization), plant maintenance (irrigation, observation, weeding, and pest and disease control), harvest and post-harvest, data collection (soil analysis data, nutrient analysis, and results components results and farm analysis data). The description of the technology package applied in this study is presented in table 1.
Table 1. The three different packages of soybean cultivation technology tested in the present study.

| Description                  | Farmer technology | Location specific technology | Recommended technology |
|------------------------------|-------------------|------------------------------|------------------------|
| Organic fertilizer:          |                   |                              |                        |
| Cow manure                   | 500 kg ha\(^{-1}\) | 2 t ha\(^{-1}\)             | 1.5 t ha\(^{-1}\)     |
| Compost                      |                   |                              |                        |
| In organic fertilizer        |                   |                              |                        |
| Urea : 50 kg ha\(^{-1}\)    | NPK : 150 kg ha\(^{-1}\) | Urea : 75 kg ha\(^{-1}\) |                        |
| SP-36 : 50 kg ha\(^{-1}\)   | KCl : -           | SP-36 : 100 kg ha\(^{-1}\) |                        |
| KCl : -                      | Dolomite : 1.5 t ha\(^{-1}\) | KCl : 100 kg ha\(^{-1}\) |                        |
| Ameliorant                   | Without ameliorant | Biochar : 1 t ha\(^{-1}\)  | Dolomite : 1 t ha\(^{-1}\) |
| Seed treatment               | No seed treatment | Bio-fertilizer Agrisoy      | Agrisoy 40 g per 8 kg seed |
| Pest and disease controls    | Chemical pesticide | Smoke liquid 6 mL L\(^{-1}\) + refugia plant | Integrated pest management (IPM) |

3. Results and discussion

3.1. Characteristics of farmers participants

From the results of the baseline survey using the direct interview method and filling out the questionnaire, it could be concluded that farmers in Margototo Village have not applied soybean cultivation technology properly and the average soybean production was still low, ranging from 400 to 500 kg ha\(^{-1}\), being far from the potential yield of the varieties used. The use of labeled seeds was not a must. The varieties used from the past until now are local varieties and varieties of Wilis and unlabelled seeds, there was no rotation of varieties. Farmers were not familiar with the soybean new superior variety produced by the Research and Development Agency which has a higher yield potential and adaptive in acid dry land.

Soybean cultivation technology applied was still conventional and based on the knowledge/experience of parents from generation to generation. The majority of farmers in Margototo Village were corn and chilli farmers, because Margototo Village is one of the corn-producing centers in East Lampung Regency. Farmers only planted soybeans, if there was a program from the Service or the government. The average cropping index in the dry land of Margototo village averages is 100 (only once a year), because it relies on rainfall. The average land ownership by farmers in Lampung is 0.5 to 1.0 ha.

The baseline survey results show that East Lampung Regency is one of the production centers for food crops (rice, corn, soybeans) in Lampung Province. Average soil reaction (pH) of the areas used for food crop development on acid dry land ranged from 4.2 to 4.5. The leading commodity in Margototo Village is corn. Farmers on first growing season plant corn or soybeans and corn and chillies intercropping in the first rainy season. Soybeans were grown in monoculture and still used conventional technology along with the use of organic and inorganic fertilizers. However, the inorganic fertilizers dosage for soybean plants was not correct and the corn plant waste (stems, leaves, cobs) has not yet been used as fertilizer. Application of lime to increase soil pH has not been carried out.

This causes farmers to generally not having the courage to take the risk of not planting food supporting crops such as upland rice, maize and cassava. Soybean is only used as a secondary crop. Besides the attractive price, the soybeans planting time must also be adjusted by farmers to local farmers’ patterns so that they do not interfere with the main crop [6]. Therefore, to be able to develop soybeans in Lampung's acid dry land, there are three key factors that must be considered, namely: (1) cropping patterns, (2) use of adaptive superior varieties for acid land, and (3) soil amelioration and optimal fertilization.
3.2. Characteristics of the study area

Before carrying out the activity, a composite soil sample was taken at the prospective location, to determine the characteristics of the land to be used. The analysis results of the physical and chemical properties of the soil are as listed in table 2.

Table 2. Selected chemical and physical properties of acid upland soil (0-10 cm depth) of Margototo, East Lampung prior to the trial.

| Parameter                  | Analysis results | Criteria* |
|----------------------------|------------------|-----------|
| Soil physical properties:  |                  |           |
| Texture (%)                | Clay             |           |
| Sand                       | 30.74            |           |
| Silt                       | 21.63            |           |
| Clay                       | 47.63            |           |
| Water content (%)          | 14.28            |           |
| Bulk density (g cc⁻¹)      | 1.39             |           |
| Soil chemical properties:  |                  |           |
| C-Organic (%)              | 1.39             | Low       |
| N-total (%)                | 0.11             | Low       |
| C/N                        | 12.63            | Moderate  |
| P-available (ppm)          | 5.83             | Very low  |
| P-total (ppm)              | 32.81            | Moderate  |
| K (me 100 g⁻¹)             | 0.37             | Low       |
| KTK (me 100 g⁻¹)           | 5.93             | Low       |
| Base saturation (%)        | 46.54            | Moderate  |
| pH-H₂O                     | 4.23             | Very sour |
| Na (me 100 g⁻¹)            | 0.09             | Very low  |
| Ca (me 100 g⁻¹)            | 1.68             | Very low  |
| Mg (me 100 g⁻¹)            | 0.62             | Low       |
| Al-dd (me 100 g⁻¹)         | 0.51             | Very high |
| H-dd (me 100 g⁻¹)          | 0.09             | Very low  |

Source: Laboratory of Soil Science, Faculty of Agriculture, University of Lampung, May 2018.
*USDA based Criteria.

Based on analysis results of soil sample taken before carrying out the assessment, it is known that the soil belonged to clay texture class with the composition of sand, clay and silt fractions of 30.74, 47.63, and 21.63% and the soil texture was is rather smooth [6]. The soil reaction was classified as very acidic with a pH value of 4.2. Acid soils are low in pH value due to their high H⁺ ion content. The availabilities of organic C and exchangeable cationse (CEC) of the soil were low, indicating that the soil was less fertile or marginal. This condition indicated that the soil required the addition of organic matter and a relatively high input of chemical fertilizers to increase the availability of nutrients in the soil. In the farmer-based technology package (package A), addition of dolomite was not yet a habit because farmers thought it would increase farming costs, even though they knew that the soil was acidic and less fertile. Therefore, the specific location package treatment (package B) applied ameliorant in the form of dolomite, corn cobs biochar, and compost as much as 1.5, 1, and 2 t ha⁻¹. The the recommended treatment package (package C) added organic matter and dolomite to increase soil pH.

Based on the Agroecological Zone map of the Lampung Province, the area was classified as dry land being suitable for agricultural development, 639,518 ha with dominant soils Ultisols, Inceptisols, and Andisols [7]. Lampung Ultisols contains 1.89 µM of Al monomeric in layers 0-15 cm and 2.29
µM in layers of 15 to 45 cm [8]. At pH 5.0 to 5.5, as much as 1% Al in Ultisol Lampung soil solution is Al monomeric [9].

The key to managing this soil type was the addition of organic matter, increasing CEC and nutrients, decreasing Al-dd, Mn, and Fe, and use tolerant varieties on soil acidity [10]. The application of organic matter can improve the physical properties of the soil, thereby increasing root growth and nutrient absorption [11].

Chemically fertile soil can be assessed from the indicators of C-organic, CEC, and high level of N, P, and K. With such initial conditions, the soil required ameliorants to raise low soil pH. The function of lime is to increase soil pH, Ca and Mg elements, the availability of P and Mo elements, reduce Al, Mn and Fe, and improve the life of microorganisms and the formation of root nodules [12]. Aluminum in acidic soils can affect the number of divalent cations absorbed by plant roots, especially Ca [13]. This shows that higher level of Al saturation content in the soil requires, higher doses of dolomite ameliorant in order to obtain optimal land productivity. If limited in availability is limited, the dolomite dose can be reduced up to ¼ x Al⁻dd (805 kg) with the addition of 2,500 kg manure [14].

Acid-tolerant varieties were able to produce higher root growth, nodules, plant height, number of pods and seed yields compared to susceptible varieties [15]. In varieties that are not tolerant on acid soils, the plants will experience growth retardation, which mainly occurs in roots [16]. Several environmental factors that influence soybean growth and yield include temperature, light [17] soil type, and soil fertility as well as the interaction of genetic factors with environmental factors [18]. Soil fertility plays an important role because one of the adaptation mechanisms for soybeans in acidic soils is its ability to absorb nutrients [19].

### Table 3. Soil analysis after the application of the three treatment technology packages in the acid dry land of Margototo Village, Metro Kibang Subdistrict, East Lampung District, (dry season in year 2018).

| Parameter                          | Farmer technology | Location specific technologies | Recommended technology |
|-----------------------------------|-------------------|--------------------------------|------------------------|
| Soil physical properties:         |                   |                                |                        |
| Texture (%)                       |                   |                                |                        |
| Sand                              | 34.61             | 32.58                          | 34.57                  |
| Silt                              | 17.71             | 19.91                          | 17.78                  |
| Clay                              | 47.62             | 47.51                          | 47.65                  |
| Bulk density (g cc⁻¹)             | 1.51              | 1.32                           | 1.42                   |
| Soil chemical properties:         |                   |                                |                        |
| C-Organic (%)                     | 1.30              | 1.22                           | 1.28                   |
| N-total (%)                       | 0.13              | 0.11                           | 0.11                   |
| C/N                               | 10                | 11                             | 11.6                   |
| P-available (ppm)                 | 61.90             | 82.92                          | 67.41                  |
| K (me 100 g⁻¹)                    | 7.83              | 8.82                           | 8.13                   |
| CEC (me 100 g⁻¹)                  | 26.44             | 26.53                          | 28.17                  |
| Base saturation (%)               | 9.65              | 5.30                           | 5.14                   |
| pH-H₂O                            | 0.04              | 0.05                           | 0.04                   |
| Na (me 100 g⁻¹)                   | 1.05              | 1.17                           | 1.14                   |
| Ca (me 100 g⁻¹)                   | 0.75              | 0.82                           | 0.79                   |

Source: Laboratory of Soil Science, Faculty of Agriculture, University of Lampung, November 2018.

After the study, it was seen that there were changes in several soil chemical and physical properties, such as changes in pH from 4.2 to 5.14, bulk density from 1.39 to 1.51 g cc⁻¹, CEC from 5.93 to 8.26 me 100 g⁻¹, N-total from 0.11 to 0.12, available-P from 5.83 ppm to 7.74 ppm, and K from 0.37 to 0.28
me 100 g⁻¹. The provision of manure, dolomite, biochar of 2, 1.5, and 1 t ha⁻¹ on acid dry land increased soil pH from 4.2 to 5.13.

According to Taufiq et al. [20], the addition of manure by 2.5 t ha⁻¹ causes changes in the chemical properties of acid soils in Central Lampung namely available P, Mn and Al and increase in soybean yields by 8 to 11%. The content of available P and Mg increased, while Al-dd decreased. To increase the production of food crops on acid soils such as Ultisols, it is necessary to add organic P (such as natural phosphate) and organic matter, in the form of manure and plant debris. According to [21] manure requires a long decomposition process so that nutrient availability is slow. This shows that giving dolomite alone can increase pH and decrease Al-dd in acidic soils, thereby increasing soil alkaline cations even without applying inorganic fertilizers and manure. The same thing was found by [22-24]. Lime that dissolves in soil will release Ca²⁺ and Mg²⁺ ions and replace H⁺ and Al³⁺ ions [25].

Ultisols soil type has low water binding capability, easily compacted, and low nutrient availability. Efforts to develop soybeans on acid dry land, and to obtain optimal soybean productivity, need to be supported by land rehabilitation measures or developing adaptive varieties on acid soil conditions. The addition of organic matter reduces the solubility of Al³⁺ and increases the available P [26]. The results of the NPK nutrient uptake analysis on the leaves of soybean plants were observed in the maximum vegetative phase (table 4).

| Nutrient (%) | Farmer technology | Location specific technology | Recommended technology |
|--------------|-------------------|------------------------------|------------------------|
| N            | 3.48              | 2.75                         | 4.34                   |
| P            | 0.27              | 0.13                         | 0.22                   |
| K            | 1.92              | 1.58                         | 1.93                   |

Source: Laboratory of Soil Science, Faculty of Agriculture, University of Lampung, September 2018.

In the table 4 above, it can be seen that in recommended technology with the addition of 40 g agrisoy per 8 kg of seeds, it appears that the N nutrient content increases and is significantly higher than without the biological fertilizer treatment. This marginal land condition is actually less suitable for soybeans, because under low soil pH soybean roots are less developed and root nodules are not well formed [20], so that nutrient uptake and nitrogen fixation are not optimal.

The increase in available P and Mg was due to the application of manure and followed by an increase in P and Mg uptake by soybean plants during flowering in both locations (Central Lampung and Tulang Bawang) [14]. The increase in available K and Ca in the acid soil of Tulang Bawang was also followed by an increase in K and Ca uptake, which was not enough to increase soybean yields in Central Lampung by applying basic fertilizers urea, SP-36 and KCl of 75, 100 and 100 kg ha⁻¹. However, it is necessary to add dolomite with a dose of ¼ Al-dd. Increased soil fertility and absorption of several nutrients were due to manure having a positive effect on increasing soybean yields. Giving dolomite up to 3/4 Al-dd in the acid dry land of Central Lampung and Tulang Bawang increased soil pH, available Ca and Mg, and decreased available Al-dd, H-dd, Fe, and Mn.

Seven days after planting there was no rain, therefore plant growth was stunted, and then nine days but on the 9th day after planting the rain fell down quite heavily, so that the plant growth was better.

Based on weather from BMKG Lampung that the forecast for the 2018 dry season, in the Metro Kibang District area, started in the third dasarian in May 2018 (table 6) with the nature normal rainfall and there was an opportunity for El-Nino to occur in 2nd semester which resulted in a longer dry season in Lampung Province [27].
Table 5. The effect of the treatments application on maximum vegetative phase of soybean growth in acid dry land, East Lampung Regency (dry season-1, 2018).

| Treatment          | Plant height (cm) | Number of branches | Number of trifoliolate leaves | Number of root nodules per plant |
|--------------------|-------------------|--------------------|-------------------------------|---------------------------------|
| Farmer             | 32.07 b           | 3.4 b              | 14.70 b                       | 2.0 b                           |
| Location specific  | 49.49 a           | 4.6 a              | 22.66 a                       | 10.6 a                          |
| Recommendation     | 45.98 a           | 5.0 a              | 20.78 a                       | 11.2 a                          |
| CV (%)             | 18.24             | 7.09               | 8.28                          | 24.00                           |

Note: The means followed by different letters in same column indicate statistically significant differences (LSD, P <0.05).

The use of agrisoy bio-fertilizers had a significant effect on the number of nodules per plant. The number of effective root nodules in the treatment packages B and C was greater than package A at the age of 45 days after planting. On acid dry land, generally the number of microbes in the soil is small, so it is necessary to provide N-fixing biological fertilizers, so that soil microbial activity increases and accelerates the development of root nodules. Agrisoy biological fertilizer functions to spur the formation of nodules, reduce the use of urea fertilizers, increase productivity and are suitable for both acid and non-acid soils [28].

Apart from drought, plant growth also experienced growth inhibition in acidic soil conditions caused by various chemical factors and their interactions. In acid soils there are major obstacles to plant growth, namely (1) increasing the concentrations of H+: H⁺ toxicity, Al:Al toxicity, and Mn:Mn toxicity, (2) decreasing the concentration of macro nutrients (cation) Mg²⁺, Ca²⁺ and K⁺ deficiencies, (3) decreasing P and Mo solubilities, (4) inhibition of root growth and water uptake: nutrient deficiency, drought and increased nutrient leaching [29].

Table 6. The effect of the application of technology packages on the components of soybean yields acid dry land, East Lampung Regency (dry season, 2018).

| Technology package         | Total number of pods per plant | Number of filled pods per plant | Root dry weight (g plant⁻¹) | Stover (g plant⁻¹) | Yields (t ha⁻¹) |
|----------------------------|--------------------------------|---------------------------------|-----------------------------|--------------------|-----------------|
| Farmer technology          | 106.94 b                       | 73.34 b                         | 11.44 b                     | 9.21 b             | 0.78 b          |
| Site specific technology   | 144.34 a                       | 101.96 a                        | 19.72 a                     | 16.76 a            | 1.32 a          |
| Recommended technology     | 152.20 a                       | 91.96 a                         | 19.74 a                     | 20.53 a            | 1.26 a          |

Note: The means followed by different letters in the same column indicate statistically significant differences (LSD, P <0.05).

Moreover, the availability of essential nutrients in the area was relatively low. Therefore, in order for soybeans to grow well, it is necessary to plant soybean varieties tolerant on soil acidity, so that the roots can grow well and absorb nutrients and water as needed.

Soybean production with the application of technology in the way farmers (package A) was as much as 0.78 t ha⁻¹ dry beans and was lower than and significantly different from the application of specific location technology package B producing as much as 1.33 t ha⁻¹ dry beans. Meanwhile, the recommended technology (package C) produced as much as 1.26 t ha⁻¹ dry beans and was not significantly different from package B.

The results obtained in dry season cropping on a very acid soil conditions caused soybean production to be not optimal. However, the results currently obtained were higher and more favorable than the conditions before the study, because based on the results of the baseline survey, the average soybean production of the farmers in Margototo village with existing technology was only 400 to 500 kg ha⁻¹, under sufficient rainfall for plant growth. In addition, there was also an increase in the
cropping index from only one planting cropping pattern on acid dry land was. The results of the soybean farming analysis in Lampung acid dry land are presented in table 7.

Table 7. Analysis of soybean farming system in Lampung acid dry land in August to November 2018.

| No. | Description of activities   | Volume | Unit (IDR) | Amount (IDR) |
|-----|----------------------------|--------|------------|--------------|
| A.  | Production means           |        |            |              |
| 1.  | Seed                       | 40     | kg         | 12,000       | 480,000      |
| 2.  | Urea fertilizer            | 100    | kg         | 1,900        | 190,000      |
| 3.  | Phonska NPK fertilizer     | 200    | kg         | 2,700        | 540,000      |
| 4.  | KCl fertilizer             | 50     | kg         | 9,000        | 450,000      |
| 5.  | Fertilizer SP36            | 100    | kg         | 2,500        | 250,000      |
| 6.  | Manure (20 sacks)          | 2,000  | kg         | 400          | 800,000      |
| 7.  | Herbicide                  | 12     | L          | 60,000       | 720,000      |
| 8.  | Starban pesticides         | 1      | L          | 80,000       | 80,000       |
| 9.  | Powdered pesticides        | 4      | sachet     | 25,000       | 100,000      |
| 10. | Fuel (premium)             | 8      | time       | 50,000       | 400,000      |
| A.  | Total cost of materials    |        |            | 4,010,000    |
| B.  | Labor wages                |        |            |              |
| 1.  | Soil cultivation           | 1      | ha         | 1,600,000    | 1,600,000    |
| 2.  | Planting                   | 14     | days       | 75,000       | 1,050,000    |
| 3.  | Weed weeding               | 12     | days       | 75,000       | 900,000      |
| 4.  | Sprinkling                 | 32     | days       | 75,000       | 2,400,000    |
| B.  | Total labors cost          |        |            | 5,950,000    |
| B.  | Total production costs (A + B) |    |            | 9,960,000    |
| C.  | Output                     |        |            |              |
|     | Package A results          | 778.44 | kg         | 10,000       | 7,784,400    |
|     | Package B results          | 1,323.32 | kg         | 10,000       | 13,233,200   |
|     | Package C results          | 1,257.08 | kg         | 10,000       | 12,570,800   |
| D.  | B/C ratio package A + irrigation cost | |       | 0.78        |
|     | B/C ratio package B + irrigation cost | |       | 1.33        |
|     | B/C ratio package C + irrigation cost | |       | 1.26        |
| E.  | B/C ratio package A + no irrigation cost | |       | 1.03        |
|     | B/C ratio package B + no irrigation cost | |       | 1.75        |
|     | B/C ratio package C + no irrigation cost | |       | 1.66        |

Economically, soybean farming in the dry season by applying package A (farmer's method) was not profitable with a B/C ratio of 0.78. Meanwhile, the application of specific location and recommended technology packages was profitable because the B/C ratio values were above 1.0 with the soybean selling price of IDR 10,000 kg⁻¹.

4. Conclusions
The use of technology components of new superior soybean varieties tolerant on acid dry land and soil fertility improvement with the addition of organic fertilizers and ameliorants was able to increase soybean yields by 30%, compared to conventional technology. There was an increase in the cropping index in acid dry land from one to two croppings a year. The B/C ratio values for the treatments of site-specific technology packages (B), recommended technology package (C), and farmer technology package (A) were 1.3, 1.2 and 0.78. Soybean production by applying site specific technology (B) producing 1.33 t ha⁻¹ dry beans was significantly higher than applying local farmers’ technology package (A) which produced 0.78 t ha⁻¹ dry beans. Whereas production of the recommended technology package (C) producing 1.26 t ha⁻¹ dry beans was not significantly different from that of the
specific location technology package (B). There were increases in soybean yields and farmers income by 66 and 30% with the application of specific location technology package (B) compared to local farmers' technology package (A).

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References
[1] Badan Penelitian dan Pengembangan Pertanian 2014 Sumberdaya Lahan Pertanian Indonesia: Luas, Penyebaran, dan Potensi Ketersediaan (in Bahasa) http://www.digilib.litbang.pertanian (accessed 21 December 2015)
[2] Hasdi 2015 Prospek konsumsi dan impor kedelai di Indonesia (in Bahasa) Jurnal Kajian Ekonomi 5 1–8
[3] Harsono A and Subandi 2013 Penuang pengembangan kedelai pada areal pertanaman ubi kayu di lahan kering masam (in Bahasa) Jurnal Iptek Tanaman Pangan 1 31–38
[4] Hidayat A and Mulyani 2002 Lahan kering untuk pertanian In: Abdurachman et al. (Eds.) Buku Pengelolaan Lahan Kering Menuju Pertanian Produktif dan Ramah Lingkungan (in Bahasa) (Bogor: Pusat Penelitian dan Pengembangan Tanah dan Agroklimat) pp 1–34
[5] Harjowigneno 2007 Ilmu Tanah (in Bahasa) (Jakarta: Akademika Pressindo)
[6] Koesrini and William E 2004 Keragaan hasil dan daya toleransi genotipe kedelai di lahan sulfur masam (in Bahasa) Bul. Agron. 32 33–38
[7] Sudaryanto B, Purwanto G, Suherlan D, Yusmeinardi and Nasrul 2002 Zonasi agroekologi Propinsi Lampung (in Bahasa) (Lampung: Balai Pengkajian Teknologi Pertanian Lampung)
[8] Harsono 2011 Efektivitas multi-isolat rhizobium dalam pengembangan kedelai di lahan kering masam (in Bahasa) Iptek Tanaman Pangan 6 57–75
[9] Taufiq A, Kuntiyastuti H, Prahor C and Wardani T 2007 Pemberian kapur dan pupuk kandang pada kedelai di lahan kering masam (in Bahasa) Penelitian Pertanian Tanaman Pangan 2 79–85
[10] Rachim, D A, Astiana, Sutanto R, Suharta N, Hidayat A, Subardja D and Arifin M 1997 Tanah merah terlapuk lanjut serta pengelolaannya di Indonesia (in Bahasa) Prosiding Seminar Sumberdaya Lahan (Buku I) Puslitana, Bogor pp 97–115
[11] Triadiati N R, Mubarik and Ramasita Y 2013 Respon pertumbuhan tanaman kedelai terhadap Bradyrhizobium japonicum toleran masam dan pemberian pupuk di tanah masam (in Bahasa) J. Agron. Indonesia 41 24–31
[12] Li Q, Hu Y, Chen F, Wang J, Liu Z and Zhao Z 2014 Environmental controls on cultivated soybean phenotypic traits across china Agric. Ecosyst. Environ. 192 12–18
[13] Kuswantoroto and Supeno 2017 Keragaan agronomi galur-galur kedelai potensial pada dua agroekologi lahan kering masam (in Bahasa) J. Agron. Indonesia 45 23–29
[14] Hasibuan H S, Sopandie D, Trikoesoemaningtyas and Wirnas D 2018 Pemupukan N, P, K, Dolomit, dan Pupuk Kandang pada Budidaya Kedelai di Lahan Kering Masam (in Bahasa) J. Agron. Indonesia 2 175–181
[15] Uguwu M I, Oyiga B C and Jandong E A 2012 Responses of some soybean genotypes to different soil pH regimes in two planting seasons African J. Plant Sci. Biotech. 3 26–37
[16] Haling R E, Simpson R J, Delhaize E, Hocking P J and Richardson A E 2010 Effect of lime on root growth, morphology and the rhizosheath of cereal seedlings growing in an acid soil Plant and Soil 327 199–212
[17] Arslanoglu F and Aytac S 2010 Determination of stability and genotype x environment interactions of some agronomic properties in the different soybean [Glycine max (L.) Merrill] Cultivars Bulg. J. Agric. Sci. 16 181–195

[18] Jeromela A M, Nagl N, Varga J G, Hristov N, Spika A K, Vasic M and Marinkovic R 2011 Genotype by environment interaction for seed yield per plant in rapeseed using AMMI model Pesquisa Agropecuária Brasileira 46 174–181

[19] Bertham R Y H and Nusantara A D 2011 Mekanisme adaptasi genotipe baru kedelai dalam mendapatkan hara fosfor dari tanah mineral masam (in Bahasa) J. Agronomi Indonesia 39 24–30

[20] Taufiq A, Kuntyastuti H, Prahoro C and Wardani T 2007 Pemberian kapur dan pupuk kandang pada kedelai di lahan kering masam (in Bahasa) Penelitian Pertanian Tanaman Pangan 2 79–85

[21] Melati M, Asiah A and Rianawati D 2008 Aplikasi pupuk organik dan residunya untuk produksi kedelai panen muda (in Bahasa) Bul. Agron. 36 204–213

[22] Agustina K, Sopandie D, Trikoesoemaningtyas and Wirnas D 2010 Tanggap fisiologi akar sorgum (Sorghum bicolor L. Moench) terhadap cekaman aluminium dan defisiensi fosfor di dalam rhizotron (in Bahasa) J. Agron. Indonesia 38 88–94

[23] Verde B S, Danga B O and Mugwe J N 2013 Effects of manure, lime and mineral P fertilizer on soybean yields and soil fertility in a humic nitisol in the Central Highlands of Kenya Internat J. Agric. Sci. Res. 2 283–291

[24] Muindi E M, Mrema J, Semu E, Mtakwa P and Gachene C 2015 Effects of lime-aluminium-phosphate interactions on maize growth and yields in acid soils of the Kenya highlands Amer. J. Agric. Forest. 3 244–252

[25] Kisinyo P O 2016 Effect of lime and phosphorus fertilizer on soil chemistry and maize seedlings performance on Kenyan acid soils J. Agric. 5 097–104

[26] Suryantini 2014 Effect of lime, organic and inorganic fertilizer on nodulation and yield of soybean (Glycine max) varieties in ultisol soils J. Exp. Biol. Agric. Sci. 2 78–83

[27] BMKG Lampung 2018 Data curah hujan Metro Kibang tahun 2018 (in Bahasa) (BMKG Lampung)

[28] Balai Penelitian Tanaman Kacang-kacangan dan Umbi-umbian 2014 Hasil penelitian utama tahun 2014 (in Bahasa) http://www.balitkabi.litbang.pertanian.go.id/ (accessed 2 September 2015)

[29] Sopandie D 2013 Fisiologi adaptasi tanaman terhadap cekaman abiotik pada agroekosistem tropika (in Bahasa) (Bogor: IPB Press)