Soil management development of suboptimal soil to improve the growth and production of potato (*Solanum tuberosum* L.)

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Abstract. Increasing potato productivity on suboptimal soil is needed since people in various food types widely consume potato. The research was conducted at the BB-Biogen Segunung-Pacet, Cipanas District, Cianjur Regency, West-Java Province that is characterized by soil with acidic reactions, medium organic matter content and low total organic-N and exchangeable-Mg, very high available-P, high exchangeable-Ca, and K. The increasing of productivity, is designed through providing various levels of lime, manure fertilizer, and Bioboost along with basic fertilizers (ZA, SP36, and KCl). Overall, there were ten treatments, namely, 1) P1 (lime level 1, manure fertilizer level 1, basic fertilizer); 2) P2 (lime level 1, Bioboost level 1, basic fertilizer); 3) P3 (lime level 2, manure fertilizer level 1, basic fertilizer); 4) P4 (lime level 2, Bioboost level 1, basic fertilizer); 5) P5 (lime level 1, manure fertilizer level 2, basic fertilizer); 6) P6 (lime level 1, Bioboost level 2, basic fertilizer); 7) P7 (lime level 2, manure fertilizer level 2, basic fertilizer); 8) P8 (lime level 2, Bioboost level 2, basic fertilizers); and 9) P9 (basic fertilizers), 10) P10 (control, without lime, Bioboost, manure fertilizer and organic fertilizer). P5 treatment resulted in the best growth and production of potato. The combination of the largest manure fertilizers and low-level lime provided the highest increase in productivity.

1. Introduction

Soil is one of the important things in the continuation of human activities. Soil plays a role in various life sectors, one of the roles, and soil plays an important role in supporting plant growth. Thus, the ability of the soil to produce plants to grow is called soil productivity. In another sense, soil productivity can be interpreted as the soil’s ability or carrying capacity in producing plants. Soil productivity is influenced by the input (management system), output (crop cultivation yield), and soil (soil type) [1]. However, not all soils have optimum potential and good characteristics to support plant growth and production.

Potatoes are horticultural crops grown on dry land with an altitude of 300 - 500 masl [2]. Potatoes are a source of carbohydrates that can replace rice. Potatoes have a high market demand. This is because potatoes are quite famous both for main processing meals, snacks, and fast-food restaurants. If the need for potatoes is related to their availability in per capita measures, it showed that the 2014 - 2018 period’s average growth is -4.04% [3]. Although this figure shows that the trend is down, Indonesia still relies on imports to meet potatoes’ needs.

In Indonesia, potato productivity is relatively low and unstable, ranging from 13 to 17 tons/ha [4]. National potato crop productivity from 1998 to 2003 respectively, 15.34 ton/ha, 14.7 ton/ha, 15.4 ton/ha,
15.6 ton/ha, 14.8 ton/ha and 15.32 ton/ha [4]. The average yield is still much lower than the average yield of developed countries, reaching 25–50 ton/ha, while potato yields in temperate climates can reach 30–40 ton/ha [5]. The current low productivity of potatoes can be caused by several factors, such as low quality of seeds, planted on suboptimal land, planted on degraded land due to high and imbalance in the use of chemicals in pesticides and fertilizers. Artificial fertilizers are still given 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 observations of agro-ecosystems in the field. The use of pesticides, both dosage, and type is not yet following the disruptive target in planting [6].

Suboptimal soil in Indonesia reaches 82% of the total dry land area [7]. Furthermore, about 107.36 million ha, or 74.3% of Indonesia's total dry land area, is classified as acid dry land (suboptimal soil). The main limitation for this soil is classified as suboptimal soil based on its acidic soil reaction. Even so, under good soil management, the acid soils and the suboptimal soils still have opportunities for a prospective agricultural area. However, the average crop productivity cultivated on these soils is not optimal, so innovations are still needed to increase crop productivity [8]. [9] research problems in suboptimal soil were caused more by the quality of chemical properties, not physical properties.

Suboptimal soils in Indonesia are generally classified as acid soils with a pH range of 5.5 or less, so it is often recommended to add lime to the soil management recommendation package. Soils with an acidic soil reaction face low availability problems of nutrients and face the threat of negative effects from high aluminium levels, which is toxic and inhibits plant growth and can even make the plants die. Thus, it is necessary to apply agricultural lime and dolomite. Adding agricultural lime and dolomite is expected to increase the availability of essential nutrients for plants. Besides increasing soil pH and increasing the availability of calcium and magnesium elements sources, giving agricultural lime and dolomite will reduce the risk of aluminium poisoning to the plants.

Most sub-optimal soils also have low carbon or organic matter content. It is easy to understand because organic matter is: 1) one of the most important soil components for the soil ecosystem, 2) a source of nutrient binding and substrate for soil microbes, and 3) an important material for improving soil fertility, both physically, chemically and biologically. Thus, efforts to improve and maintain organic matter content to maintain tropical soils' productivity need to be done [10, 11]. Organic material comes from plants and animals' remains, which continually changing due to the influence of physical, chemical, and biological processes. The organic material consists of carbohydrates, crude protein, cellulose, hemicellulose, lignin, and fat. The use of organic fertilizers can improve soil structure and promote the development of micro-population of soil organisms. Organic matter physically promoted granulation, reduced plasticity, and increased soil water holding capacity [12]. Soil physical properties greatly affected plant growth and production [13].

Besides using inorganic fertilizers, solid organic fertilizers combined with liquid organic fertilizers will provide an excellent opportunity to increase production. It is because liquid organic fertilizers will stimulate plant growth and increase the number of leaves formed so that the photosynthesis process will produce photosynthate to support tuber formation and filling [14]. Thus, the soil management package needs to be carefully designed according to the soil's condition or quality and the type of plants that will be cultivated.

This study aims to develop a soil management scheme and improve suboptimal soil for horticulture cultivation, mainly potato, through a combination of inputs needed to optimize the growth and productivity of potato plants.

2. Methodology

2.1. Location and time of research
The research was conducted from early July to the end of October 2020. The demonstration plot research was carried out at the BB-Biogen field station in Pacet-Cipanas, West Java Regency, Banten Province, Indonesia.
2.2. Treatment design and composition
Setting and selection of treatment were determined by considering the results of soil conditions evaluation. Horticultural crops cultivation such as potato still requires extra soil management, especially heavy fertilizer, such as agricultural lime, organic matter, soil conditioners, or amendments. The combination of these three elements was formulated into ten treatments, including one control treatment. Except for control, the other nine treatments were given basic fertilizer of ammonium sulfate (ZA), SP 36, and KCl. Details of the ten treatments are presented in Table 1.

This research used a Completely Random Design with ten treatments and 3 (three) replications, so the total research plots were 30 units. Each plot's size was 5 m × 6 m, so each plot area was 30 m². The distance planting was 20 cm × 70 cm.

Table 1. Treatment at the potato demonstration plots.

| Treatment | Lime Dosage | Manure Dosage | Bioboost Soil Amendment Dosage | Basic Fertilizer | Symbol |
|-----------|-------------|---------------|--------------------------------|------------------|--------|
| P1        | Dose 1      | Dose 1        | Dose 0                         | ZA + SP36 + KCl  | K1M1B0+|
| P2        | Dose 1      | Dose 0        | Dose 1                         | ZA + SP36 + KCl  | K1M0B1+|
| P3        | Dose 2      | Dose 1        | Dose 0                         | ZA + SP36 + KCl  | K2M1B0+|
| P4        | Dose 2      | Dose 0        | Dose 1                         | ZA + SP36 + KCl  | K2M0B1+|
| P5        | Dose 1      | Dose 2        | Dose 0                         | ZA + SP36 + KCl  | K1M2B0+|
| P6        | Dose 1      | Dose 0        | Dose 2                         | ZA + SP36 + KCl  | K1M0B2+|
| P7        | Dose 2      | Dose 2        | Dose 0                         | ZA + SP36 + KCl  | K2M2B0+|
| P8        | Dose 2      | Dose 0        | Dose 2                         | ZA + SP36 + KCl  | K2M0B2+|
| P9        | Dose 0      | Dose 0        | Dose 0                         | ZA + SP36 + KCl  | K0M0B0+|
| P10       | Dose 0      | Dose 0        | Dose 0                         | -                | Control|

Remarks:
- Lime (K) : Dose 0 = 0 ton/ha; Dose 1 = 1 ton/ha; Dose 2 = 3 ton/ha.
- Manure (M) : Dose 0 = 0 ton/ha; Dose 1 = 15 ton/ha; Dose 2 = 30 ton/ha.
- Bioboost Organic Soil Conditioner (B): Dose 0 = 0 ton/ha; Dose 1 = 1 liter/ha; Dose 2 = 2.5 liter/ha.
- Basic Fertilizer (+) : ZA = 300 kg/ha; SP 36 = 250 kg/ha; KCl = 250 kg/ha.

2.3. Soil sampling, field observation, demonstration plot, and laboratory analysis

2.3.1. Field observation and soil sampling. 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 depth and soil drainage. Soil sampling consisted of composite soil samples for laboratory analysis of soil chemical properties and soil texture. Sample (core sample) was taken to determine the bulk density of the soil.

2.3.2. Demonstration plot. Land preparation, soil tillage, planting, and maintenance, until harvesting were conducted on the plots based on the treatment designed. The size of each plot was about 5 x 6 m with an area of 30 m². The total plots were 30 as derived from 10 treatments with 3 (three) replications. Varietas of potato in this research was Granola FO. Height of plant at 40 days and 70 after planting representing vegetative parameter were observed and measured. While for the generative parameter, the fresh weight of the potato tuber was observed and measured.

2.3.3. Laboratory analysis. Laboratory analysis of soil chemical properties consists of soil reaction (pH), organic carbon content, total N, available P, potassium, exchangeable calcium and magnesium, cation exchange capacity, and aluminium saturation. Laboratory analysis was conducted at Soil Chemistry and Fertility Laboratory, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University.
2.4. Data Analysis
Data analysis using Microsoft Excel. Data from each plot and their replications were analyzed using variance with α at 5% level and then followed by Duncan Multiple Range Test (DMRT) with α at 5% level to test the significant difference of the treatment.

3. Results and discussion

3.1. Initial evaluation of soil conditions
The soil was used as the demonstration plot could not support the high potato production target. The initial evaluation results showed that the soil conditions had good physical support but were not supported by good soil chemical properties. The soil’s chemical properties were classified as having an acidic soil reaction. Other constraints were low in total N and exchangeable potassium and moderate organic carbon and exchangeable calcium, magnesium, and potassium levels. A description of soil's chemical and physical properties at the demonstration plot location is presented in Table 2. To increase the productivity of such soil, it is necessary to add agricultural lime to improve the soil so that it does not have an acidic soil reaction and the addition of organic matter or manure.

Table 2. Characteristics of several main soil parameters.

| No | Parameters                                      | Unit     | Number  | Category          |
|----|------------------------------------------------|----------|---------|-------------------|
| 1  | Soil acidity (pH)                               | %        | 5.10    | Acid              |
| 2  | Organic carbon (C-Org)                          | %        | 2.85    | Moderate          |
| 3  | Total nitrogen (N-Total)                        | %        | 0.14    | Low               |
| 4  | Phosphorus (P) available                        | ppm      | 53.24   | Very high         |
| 5  | Calcium (Ca) interchangeable                    | cmol+/kg | 6.76    | Moderate          |
| 6  | Magnesium (Mg) interchangeable                  | cmol+/kg | 0.76    | Moderate          |
| 7  | Potassium (K) interchangeable                   | cmol+/kg | 0.10    | Low               |
| 8  | Cation exchange capacity (CEC)                  | cmol+/kg | 28.76   | High              |
| 9  | Aluminum saturation                             | %        | 1.01    | Very low          |
| 10 | Texture                                         | Clay loam|         | Very good         |
| 11 | Effective depth                                 | cm       | 94      | Deep              |
| 12 | Drainage                                        |          | -       | Good              |
| 13 | Soil bulk density                               | g/cc     | 0.85    | Very good         |

SQR-Plus* 3.82 pH,K Slightly good
PSPI-Plus* 3.62 pH,K Slightly high

*Rachman et al. [15].

According to [15], the study site's soil has SQI Plus of 3.82 pH,K and PSPI Plus of 3.82 pH,N,K. It means that the soil quality is categorized as slightly good and slightly high potential soil productivity with limiting factor of acid soil reaction or low soil pH and low exchangeable K and total N. To raise potato production, liming and organic fertilizer or manure is required. To improve soil condition and released soil nutrient adsorbed, absorbed, and tied up by other compounds, a soil conditioner should be allotted. In this research, Bioboost, an organic soil conditioner, was applied.

3.2. Effect of treatment on growth and production of potatoes
For potato tuber production, the highest tuber weight was produced from P7, a combination of lime application dose 2 (3 ton/ha) and manure dose 2 (30 ton/ha) which production reached 18.95 ton/ha, followed by P5, a combination of lime application dose 1 (1 ton/ha) and dose two manure (30 ton/ha) with a production of 18.30 ton/ha, and P3, a combination of lime application dose 2 (3 ton/ha) and the dose of manure 1 (15 ton/ha). The complete tuber production from each treatment can be seen in table 3 and figure 1.
Table 3. Effects of treatment on plant height and weight of potato tubers.

| Symbol of Treatment | Treatment      | Height of plant (cm) | Weight of potato per plot (kg) | Weight of potato per plant (g) | ton/ha |
|---------------------|----------------|----------------------|--------------------------------|--------------------------------|--------|
|                     |                | 40 days 70 days      |                                 |                                |        |
| P1                  | K1M1B0+        | 35.5 a 58.0 ab       | 809.70                         | 21.93                          | 16.87ab|
| P2                  | K1M0B1+        | 32.1 ab 55.7 ab      | 757.57                         | 20.51                          | 15.78b |
| P3                  | K2M1B0+        | 31.7 ab 58.0 ab      | 850.77                         | 23.04                          | 17.72ab|
| P4                  | K2M0B1+        | 26.4 cd 56.8 ab      | 620.93                         | 16.82                          | 12.94c |
| P5                  | K1M2B0+        | 28.6 bc 59.3 a       | 878.20                         | 23.79                          | 18.30a |
| P6                  | K1M0B2+        | 31.1 b 59.3 a        | 798.67                         | 21.63                          | 16.64ab|
| P7                  | K2M2B0+        | 23.2 de 52.3 bc      | 910.30                         | 24.65                          | 18.96a |
| P8                  | K2M0B2+        | 23.1 de 52.0 bc      | 608.90                         | 16.50                          | 12.69c |
| P9                  | K0M0B0+        | 20.2 e 44.3 d        | 559.23                         | 15.15                          | 11.65cd|
| P10                 | Control        | 21.2 e 48.7 cd       | 455.90                         | 12.35                          | 9.50d  |

Remark: numbers followed by the same letter in the same column are not significantly different by Duncan Multiple Range Test with α at 5% level.

Compared with the control, the percent increase of other tuber production treatments can be seen in table 4. Treatment P7 results in the largest increase, 100%, so that the ratio of the increase in tuber production to control reached 2.00. The next highest increase is followed by P5 that received an increase of 93%, P3 87%, and P1 78%. All of them are produced by a combination of applying lime and manure. The highest production obtained from the application of the combination of lime with the Bioboost soil conditioner is achieved by P6, namely, 1 ton/ha of lime and 2 litres/ha of Bioboost with an increase in production of 75%, followed by P2, 1 ton/ha of lime and 1 litre/ha of Bioboost and with an increase in production of 66%, followed by P4, giving lime with a dose of 3 ton/ha and Bioboost 1 litre/ha, with an increase in production of 36%. The increase in production obtained by applying ZA, SP 36, and KCl basic fertilizers without using lime, manure, and Bioboost reached 23% compared to control, without any application (see table 4).

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

| Treatment | P1   | P2   | P3   | P4   | P5   | P6   | P7   | P8   | P9   | P10  |
|-----------|------|------|------|------|------|------|------|------|------|------|
| Production (ton/ha) | 16.87 | 15.78 | 17.72 | 12.94 | 18.30 | 16.64 | 18.96 | 12.69 | 11.65 | 9.50 |
| The ratio of tuber production to control | 1.78  | 1.66  | 1.87  | 1.36  | 1.93  | 1.75  | 2.00  | 1.34  | 1.23  | 1.00 |
| Production increased over control (%) | 78    | 66    | 87    | 36    | 93    | 75    | 100   | 34    | 23    | 0    |
Figure 1. Illustration of a comparison of treatments effect on potato tuber weight, the most excellent treatment (P7) effect was to increase tuber production two times compared to control.

There is a close correlation between the height of the plant and the weight of the tuber. At 40 days after planting, the correlation coefficient (R) value is 0.624 and the determination coefficient ($R^2$) 0.389. While for 70 days after planting, the value of correlation coefficient (R) is 0.6689 and determination coefficient ($R^2$) 0.475. It indicated that the vegetative phase quite affected the generative performance. The tuber weight production increased by the combination of lime and manure 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 conditions. The increase in soil fertility and soil productivity with the application of manure can be explained by adding to the 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 plant and soil aeration in maintaining a good gases supply needed by plants.

Drought attacks encountered, particularly during the last two weeks of September 2020 and the first of October 2020 when the plant was approaching and early in the tuber formation periods, result in not achieving the expected potato tuber production target, which is around 30 tons/ha. Manual watering efforts carried out through the provision of clean water were still unable to overcome the problem and meet the water needs for plants when water sources for irrigating that are usually available at the research location are to prevent the plants from stress.

Application of compost or manure could increase potato plant growth, fresh potato tuber, and nutrient absorption of N, P, and K of potato [16]. The research was done by Nyiraneza dan Snapp [17] showed that combination manure and N-an organic fertilizer on potato cultivation produced the highest N plant absorption and fresh potato tuber.

3.3. Evaluation on soil management development design for suboptimal soil improvement
Suboptimal soil such as those in the study location is 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 soil management design based on soil conditions has shown expectations as targeted. The combination of applying lime and manure at the start of the growing period had shown the expected results. From the results of potato tuber production, it can also be seen that the effect of the combination treatment of lime with a dose of 3 ton/ha and manure at 30 ton/ha can increase production by 100%. 
Organic matter has a very crucial and important role in determining soil fertility level [18]. Soil that is optimal for plant growth requires at least 2% of soil organic matter content [19]. To maintain this level of soil organic content, agricultural land needs additional organic material at least 8 – 9 ton/ha per year. The application of organic material can improve soil fertility and the fresh tuber weight of potato [20]. Application of manure on potato farm produced potato tuber with the highest carbohydrate and protein and nutrients content of P, K, Ca, Mg, dan Zn in tuber and stem of potato plant [21].

Even if there had been no onset of drought during the last two weeks of September 2020 and the first week of October 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 affect inhibiting growth.

The experience from this research shows that the development of appropriate soil management design can significantly increase the growth and production of potato tubers. In this study, the combination of lime application with doses ranging from 1 ton/ha to 3 ton/ha and manure at a dose of 15 ton/ha to 30 ton/ha for the first planting season has shown an increase in soil productivity in the research location which can be classified into 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
The development of soil management design for suboptimal soils on cultivating horticultural crops at the research site increases the fresh tuber weight of potato significantly. Through a combination design of lime at a dose of 1 to 3 ton /ha and manure at a dose of 15 ton/ha to 30 ton/ha, the treatments significantly increased potato tuber production up to 100 % compared to the control treatment. P7 treatment (application of 3 tons of lime and 30 tons of manure) produced the highest yield of fresh tuber production, i.e., 18.96 tons/ha, twice the control plot (9.50 tons/ha). The soil management package needs to be supported by irrigation or watering schemes to prevent crops from drought stress to achieve higher production. The water availability of soil very much influences the production of potato tubers during tuber formation and enlargement.

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References
[1] Nurmala T, Sutono A D, Rodjak A, Suganda T, Natasasmita S, Simarmata T, Salim E H, Yuwariah Y, Sendjaja T P, Wiyono S N and Hasani S 2012 Pengantar Ilmu Pertanian (Yogyakarta: Graha Ilmu)
[2] Indonesian Center for Horticulture Research and Development of Republic of Indonesia 2015 Budidaya tanaman kentang Retrieved: http://hortikultura.litbang.pertanian.go.id/berita-692-budidaya-tanaman-kentang.html
[3] Komalasari W B 2018 Statistik Konsumsi Pangan (Jakarta: Center For Agricultural Data And Information System Ministry of Agriculture Republic of Indonesia)
[4] Lehar L 2012 Pengujian pupuk organik ajen hayati (Trichoderma sp) terhadap pertumbuhan kentang (Solanum tuberosum L) J. Penelitian Pertanian Terapan 12 (2) p 115 – 124
[5] Rukmana R 1997 Kentang Budidaya dan Pasca Panen (Yogyakarta: Kanisius)
[6] Tarigan A and Hanum Hamidah 2019 Status hara N, P, dan K tanah dan korelasinya dengan produksi kentang (Solanum tuberosum. L) di Kabupaten Karo J. Tanah dan Sumberdaya Lahan 6 (1) p 1105 – 1111
[7] Indonesian Agency for Agricultural Research and Development Ministry of Agriculture Republic of Indonesia (IAARD) 2014 Sumberdaya Lahan Pertanian Indonesia: Luas Penyebaran Dan Potensi Ketersediaan (Bogor: IAARD Republic of Indonesia)
[8] Nurida L N and Rachman A 2013 Alternatif pemulihan lahan kering masam terdegradasi dengan formula pembenah tanah biochar Typic Kanhapludults Lampung in Proceeding Seminar Nasional Teknologi Pemulihan dan Pemilihan Lahan Terdegradasi (Bogor)

[9] Rachman L M 2019 Karakteristik dan variabilitas sifat – sifat fisik tanah dan evaluasi kualitas fisik tanah pada lahan suboptimal in Herlinda S et. al. ed Proceeding Seminar Nasional Lahan Suboptimal 2019 (Palembang) p 132 – 139

[10] Onunka N A, Chukwu L I, Mbanasor E O and Ebeniro C N 2012 Effect of organic and inorganic manures and time of application on soil properties and yield of sweet potato in a tropical ultisol J. Agric. Soc. Res. 12(1) p. 183-194

[11] Nazari Y A, Soemarno L dan Agustina 2012 Pengelolaan kesuburan tanah pada pertanaman kentang dengan aplikasi pupuk organik dan anorganik Ind. Green Tech. J.11(1) p. 7-12

[12] Brady N C 1990 The Natural and Properties Soils (New York : Macmillan Publishing Company)

[13] Rachman L M, Wahjunie E D, Brata K R, Purwakusuma W dan Murtilaksono K 2013 Fisika Tanah Dasar (Bogor: IPB University)

[14] Samadi 2007 Kentang dan Analisis Usaha Tani (Yogyakarta: Kanisius)

[15] Rachman L M, Hazra F dan Anisa R 2020 Efek Kombinasi Pemberian Kapur, Pupuk Kandang, Dan Pembenah Tanah Bioboost Terhadap Pertumbuhan Dan Produksi Kentang (Solanum tuberosum L) Serta Aktivitas Mikroba Tanah

[16] Jaipaul J, Sharma S dan Sharma A K 2011 Effect of organic fertilizers on growth, yield and quality of potato under rainfed conditions of central himalayan region of Uttarakhand Potato J. 38 (2) p. 176-181

[17] Nyiraneza J dan Snapp S 2007 Integrated management of inorganic and organic nitrogen and efficiency in potato systems SSSAJ 71(5) p. 1508-1515

[18] Diacono M and Montemurro F 2010 Long-term effects of organic amendments on soil fertility A review Agro Sust. Dev.30 (2) pp 401-422

[19] Hairiah K, Kasniart D N, Van Noordwijk M, dde Foresta H dan Syekhfani 1996 Litterfall, above and bellow ground biomass and soil properties during the first year of chromolaena odorata fallow Agrivita 19

[20] Lynch D H, Zhong Z, Zebarth B J dan Martin R C 2008 Organic amendment effects on tuber yield and quality, plant N uptake and soil mineral N under organic potato production J. Renew AgricFood Syst. 23 (3) p 250-259

[21] Islam M R dan Nahar B S 2012 Effect of organic farming on nutrient uptake and quality of potato J. Environ Sci. Nat. ResoUr. 5(2) p. 219-224