The Effect of Mulch and Fertilizer on Soil Temperature of a Potato Growth

Sofyan Samad
Faculty of Agriculture, Khairun University, Ternate North Maluku, 97719, Indonesia.
Tel: + 6285255932109 E-mail: *sofyan.samad1970@gmail.com*

Muslimin Mustafa
Departement of Soil Science, Faculty of Agriculture, Hasanuddin University,
South Sulawesi, 90245, Indonesia.
Tel:+62-411-587050 Fax: +62-411-586014

Baharuddin
Departement of Plant Pests and Diseases, Faculty of Agriculture, Hasanuddin University,
South Sulawesi, 90245, Indonesia.
Tel:+62-411-587100 Fax: +62-411-587100 E-mail: *baharunhas@yahoo.com*

D. Agnes Rampisela
Departement of Soil Science, Faculty of Agriculture, Hasanuddin University,
South Sulawesi, 90245, Indonesia.
Tel:+62-411-587050 Fax: +62-411-586014 E-mail: *agnes.rampisela@gmail.com*

Abstract: The aim of this research is to investigate the effect of the temperature decrease by using mulch and fertilizer on the soil to potato. The study was conducted in November 2008 until June 2009 which was designed in a separate split plot design. The treatments consists of two factors and three replications, namely Factor I: The main plot consist of four treatments of mulch without mulch (Mo), Cover crops *Arachis pintoi* (Ma), rice straw mulch (Mj) and Black silver plastic mulch (Mp). Factor II: The sub-plot consists of three treatments: without fertilizer (P_0), NPK 300 kg /ha (P_1) and a combination of organic fertilizer 20 tons / ha nonorganic fertilizer (NPK), of 300 kg/ha (P_2). The parameter was the surface erosion rate, the growth and production of potatoes, that were observed, that is environment components: 1) the measurement of soil temperature at night.and the plant component (the number of tubers). The study showed that all types of mulch effectively decrease soil temperature. The rice straw mulch ttreatment with a combination of organic and anorganic fertilizer produced the lowest soil temperature of 17.82 ^{0}C. It is capable of recording the soil temperature up to 6.43 ^{0}C. The treatment of types of mulch in combination with organic and anorganic fertilizer produced the highest number of tuber compared to other types of treatments. However, treatment types of mulch are given a combination of organic and anorganic fertilizer resulted in the highest number of tubers. Future work should focus on the use of mulch and fertilizer in getting the optimum growth of potato.

Keywords: Potato; mulch; fertilizer; soil temperature; soil erotion

1. Introduction

Potato plants are herbaceous plants, annuals and grow in cold climates or low soil temperatures. This plant is native to South America, from the plateau in Chile, Peru, Mexico and spread to the whole country in the world. Besides supporting the potato crop diversification program as a source of food to increase exports of commodities and raw materials of the food industry, agricultural activities in Indonesia must change. It is therefore in need of efficient technology and sustainable farming in an effort to preserve agricultural land

The highland potato as high economic value, because of as a source of carbohydrates and proteins that can be used as an alternative to rice to support food security. It can be made various kinds of food, either in the form of stew, chips, or fried. In addition, the potato easily processed into a variety of snacks and prepared foods such as French fries though, instant potato, potato skins and also beneficial for beauty treatments and others (Wattimena, 2006).

The potatoes have low calorie, high nutrition and protein to carbohydrate ratio is higher than other root crops (Neitherhouser, 1993; Suyamto et al, 2005; Wattimena 2006). Each 100 g of potatoes containing 83 cal calories, 2g protein, 0.1g fat, 19.1g carbohydrates, 11 mg calcium, phosphorus 56 mg, iron 0.70 mg and 0.11 mg vitamin B 191 (Rubatzky and Yamaguchi, 1998). High nutritional value and causing widespread food processing plant is very potential to be developed as well as having high export prospects

Fairly rapid population growth and changes in people's lifestyles are like fast food and restaurant food growing potato processing industry, causing demand for potatoes from year to year continues to increase (Gunarto, 2003). Demand for industrial potato chips in the country in 2000 reached 3000 ton. This demand continues to increase up to 6000 tons per year. Not to mention the demand for French fries potatoes around 16,800 tons per year and can only be filled with 4,300 tons per year (Anonymous, 2002). On the other hand the domestic production is still very low and can only meet 25% of the total requirement so as to meet all the demand, and then the rest is still to be imported.

Potential development area of potatoes in Indonesia is still very large, there are ± 11.33 million ha of land located at an altitude of 700 m above sea level, but the area of 65.420 ha of new has been used (Laksana, 2006). The land is generally found outside the island of Java, such as Aceh Province, North Sumatra, West Sumatra, Jambi, Bengkulu, South Sulawesi, North Sulawesi and Papua (Wattimena, 2006),

Indonesian potato productivity is still low because only reached 13 ton/ha (DJBPH, 2005), and in 2007 increased to 16.79 ton/ha (Anonymous, 2007). Productivity is still far from production potential that can reach 40 ton/ha. These results are still very low when compared with the achievements of countries - developed countries like Australia 50 ton/ha, Japan 31.7 ton/ha, Korea 20 ton / ha, and the U.S. reached 25 ton/ha (Fageria *et al*. 1991). The low productivity of Indonesian potato is affected by several things, among others, the limited use of healthy seeds and top quality, high pest/disease and poor mastery of new technologies (Baharuddin, 2008). The low production is also due to the planting of potatoes still confined to upland areas above 900 m above sea level as it relates to soil temperature conditions necessary to support potatoes tuber. Whereas the highlands which are processed continuously will cause a decline in soil fertility, plant and disturbance accumulation of organism's erosion surface so easy it can cause land productivity and quality of production decreased (Purbiati *et al*. 2008).

To increase the potato production it is necessary to study the development of potato planting area at the medium highland land. Agro ecosystem plain medium (middle) is a transition region between the highlands and lowlands, where the land area in Indonesia plain medium reached 61.16 million ha. The topography varies from gently sloping plain medium, wavy, undulating to mountainous. The data show medium with plain land sloping to undulating topography is 24.29 million ha of land is likely to potato crop development (Djaenudin, 2008).

Medium-lying land is land that has the potential to increase production of potato, but the effort was still having problems, such as high soil temperature and low soil moisture (Wicaksana, 2001). High soil temperatures can changes in stolon to tuber inhibited (Stark and Love, 2003). In addition, the high temperatures will increase the rate of respiration and decrease the rate of photosynthesis which causes low translocation of assimilates to roots and tubers, resulting in inhibition of the formation and enlargement of tubers (Marquis *et al.,* 1996). Potato plants require cool temperatures, between 20 ^{0}C with 90 % humidity (Sunarjono, 2007). Thus we need some modification efforts microenvironment that is able to stimulate the formation of potato tubers in plain medium. Modifying the microenvironment can be done with a variety of technological approaches like a planting, mulching rice straw or plastic mulch, organic and inorganic fertilizer or a combination of both, which is expected to form the appropriate environment for planting potatoes. Based on these problems, it is necessary to research on how to create plain medium agro ecology on land that can be equivalent to the micro-climate of the plateau, surface erosion can be reduced, maintained productivity and sustainable agricultural activities.

2. Materials and Methods

The trial lasted from November 2008 until June 2009. Experiments carried out on dry land dakwah Hamlet Village High Muzzle Parigi District of Gowa, which lies at an altitude of 700 m above sea level. A night temperature of 25.55 ^{0}C at a depth of 10 cm with 60 % soil moisture was recorded. A Factorial design was performed as follows:

(a) Factor I: The main plot consist of four treatments of mulch without mulch (Mo), Cover crops *Arachis pintoi* (Ma), rice straw mulch (Mj) and Black silver plastic mulch (Mp).

(b) Factor II: The sub-plot consists of three treatments: without fertilizer (P_0), NPK 300 kg/ha (P_1) and a combination of organic fertilizer 20 ton / nonorganic fertilizer (NPK), of 300 kg/ha (P_2). The material used consists of 125 kg potato seeds granola variety of Loka Bantaeng Indonesia, with cover crops *Arachis pintoi* ,1000 pot plants, 1 ton of rice straw and black plastic silver 1 roll, and chicken coop organic fertilizer of 20 ton/ha.

2.1 The Tools

A digital thermo-hygrometer temperature gauge humidity and air and digital probe thermometer temperature measuring instrument were gauged in the soil. The soil tester tool was used to measure soil moisture and soil pH while an altimeter was used to measure altitude. A Factorial design with Factor I as the main plot treatments consisted of four types of mulch that is (M): without mulch (control) (M_O), *Arachis pintoi* cover crops (Ma), Rice straw (Mj), black silver plastic (Mp). Meanwhile, Factor II was for the subplots consisted of three treatments, (P): without fertilizer (control) (P_0), NPK 300 kg/ha (P_1), the combination of organic fertilizer. A 20 ton/ha and an organic fertilizers (NPK) of 300 kg/ha (P_2) were applied. The soil surface erosion rate, the growth and production of potatoes were measured.

2.2 Land Preparation

The activities for potato cultivation system include the use of cover crops with rice straws and plastic mulches, land preparation activities, preparation of seed, planting, and maintenance of the plant. For land preparation and seedbed technique, a hoe was used to dig the soil to a depth of 30 cm. The soil was then crumbled before drying for at least 10 days. The ground was dug for the second time until the soil was completely loose while flattened. Soil piles were built measuring 200 cm wide and 300 cm long, 30 cm high and 30 cm spacing between beds and wall beds covered with black plastic. This was purposely done to streamline the raised bed aeration (air exchange land), reinforcing the founding roots, simplify absorption water and nutrients, as well as drain rainwater. The organic fertilizer or chicken manure as much as 20 ton/ha was spread by making a planting hole with a size of 20 cm width and 10 cm depth. The soil was then mixed and blended with an inorganic fertilizer (NPK Nitrophoska of 300 kg/ha) was given for 5 g per plant 20 days after planting. *Arachis pintoi* was planted with an organic fertilizer input at a planting distance with potatoes of 25 cm. Cover crops, *Arachis pintoi* was planted at depths of 8 to -10 cm and the roots started to grow two weeks after planting. In order to obtain a uniform growth of *Arachis pintoi,* they were planted at a distance of 25 cm covering the entire surface of the ground only after three months. *Arachis pintoi* were wrapped to avoid dryness during transportation. Irrigation is critical during the initial period of growth to keep the plant moist but not too wet. Weeding is necessary during the initial period of growth using a hoe or revoked. Rice straw mulch was spread on the bed as thick as 3-4 cm after the seedbed was fertilized with organic fertilizer. The soil was covered with black colored plastics facing downwards and the silver colored side exposed with soilbeds reinforced with bamboo pegs are attached at both sides of the beds with 15 cm distance between the pegs. Planting holes were later drilled in the plastic mulch form planting purposes.

2.3 Preparation of Seed

Seeds and superior quality are the success factors determining potato planting. To avoid seed mortality, it is critical that the preparation of seed derived from improved varieties should be free of pests and diseases. During the storage of seeds for a period of six months, 2 cm long sprout leaves were observed with no broken tubers.

2.4 Planting

Planting beds were prepared with planting holes of 50 cm spacing between rows. The spacing between plant rows was 30 cm so that there were 36 holes of 10 cm deep in each plant bed. Young potatoes with a 2 cm sprout were then inserted one by one into the planting hole with the buds facing up position and then backfilled with loose soil thickness of 5 cm.

2.5 Plant Maintenance

Potato plants will grow well if carefully maintained. Maintenance activities include activities such as watering once at the beginning of the planting. During replanting, watering was done twice to the potatoes at the age of 20 and 25 days after planting. A total of 4-5 seeds per plot were properly watered and maintained.

2.6 Soil Temperature and Tubers Measurement

Parameters measured includes soil temperature at night and the total potato tubers. The data obtained were analyzed using Univariate Analysis of Variance (SPSS15) followed by Honestly Significant Difference (HSD) and Turkey's Honestly Significant Difference tests.

3. Results and Discussion

3.1 Effect of Fertilizer Types of Mulch on Soil Temperature

The type and amount of mulch cover do affect soil temperature of the potato growth. Figure 1a at the time of the potato crop was 40 HST which showed that the treatment without mulch (Mo) with a combination of organic and inorganic fertilizers (P_2), produced a soil temperature of 25.85 ^{0}C. While treatment of *Arachis pintoi* (Ma) without fertilizer (P_0) resulted in soil temperature of 20.25 ^{0}C which is lower when compared to other treatments and were able to lower the temperature of the ground level of 5.3 ^{0}C. Treatment of rice straw mulch (Mj) with a combination of organic and inorganic fertilizers (P_2) produces soil temperature at 21.46 ^{0}C and can lower the soil temperature of the ground level by 4.39 ^{0}C. Similarly, treatment of plastic mulch (Mp) with a combination of organic and inorganic fertilizers (P_2) produces soil temperature of 21.25 ^{0}C and can lower the temperature of the ground level by 4.6 ^{0}C.

The soil temperature after 45 days of potato planting showed that the treatment without mulch (Mo) with a combination of organic and inorganic fertilizers (P_2) produces a temperature of 24.35 ^{0}C which is the highest temperature when compared with other treatments. The treatment of *Arachis pintoi* (Ma) with a combination of organic and inorganic fertilizers (P_2) lead to a reduced soil temperature of 19.65 ^{0}C with a reduction of 4.7 ^{0}C. Treatment of rice straw mulch (Mj) with a combination of organic and inorganic fertilizers (P_2) produces soil temperature of 17.87 ^{0}C and were able to lower the temperature of the ground level by 6.48 ^{0}C. Similarly, treatment of plastic mulch (Mp) with a combination of organic and inorganic fertilizers (P2) produces soil temperature of 18.25 ^{0}C and to reduce the rate of soil temperature of 6.1 ^{0}C.

The soil temperature at the time of the potato crop was 50 days after planting showed that the treatment without mulch (Mo) with any fertilizer (P_0) produces a temperature of 25.41 ^{0}C which is the highest temperature when compared to other treatments. When *Arachis pintoi* (Ma) with a combination of organic and inorganic fertilizers (P_2) produces soil temperature of 18.45 ^{0}C and to reduce the rate of soil temperature of 5.8 ^{0}C it was treated with rice straw mulch (Mj) and a combination of organic fertilizer and inorganic (P_2) produces soil temperature of 17.82 ^{0}C.

This enable it to lower the temperature of the ground level of 6.43 ^{0}C. Similarly, of plastic mulch (Mp) with a combination of organic and inorganic fertilizers (P_2) produces soil temperature at 18.21 ^{0}C and is able to lower the temperature of the ground level of 6.04 ^{0}C. Comparison of soil temperature of each type of mulch at every level of fertilization is presented in Table 1 and Figure 1.

Table 1. Comparison of soil temperature on into the night with 10 cm of each type of mulch at every level of fertilization

treatment	Soil temperature (^{0}C)		
	Age of Plant		
	40 days after planting	45 days after planting	50 days after planting
MoP0	25.55	25.49	25.41
MaP0	20.25	20.25	19.85
MjP0	21.46	18.86	18.75
MpP0	21.45	18.74	18.72
MoP1	25.75	24.45	24.32
MaP1	20.32	19.77	18.63
MjP1	21.45	18.64	18.56
MpP1	21.25	18.85	18.68
MoP2	25.85	24.35	24.25
MaP2	20.32	19.65	18.45
MjP2	21.46	17.87	17.82
MpP2	21.25	18.25	18.21

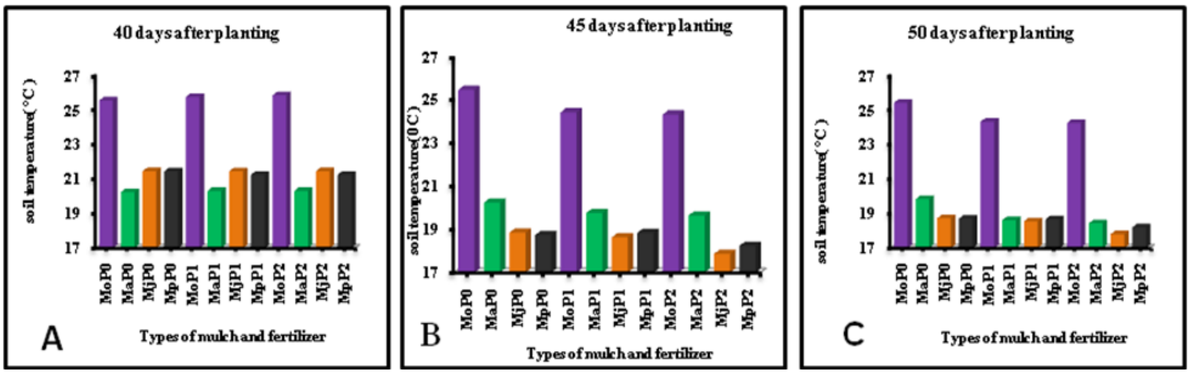

Figure 1. Histogram comparison of soil temperature to each type of mulch at every level of fertilization

3.2 Effect of mulch type and fertilizer on Total Bulbs Per Plot

ANOVA showed a highly significant interaction between the influence of the type of mulch and fertilizer on potato tuber number per plot. This indicates that treatment *Arachis pintoi* are given a combination of organic and inorganic fertilizers (MaP_2) visually produces the highest number (64.3) of tubers per plot when compared with other treatments and significantly different with treatment *Arachis pintoi* an organic fertilizers, only (MaP_1) and *Arachis pintoi* were not given fertilizer (MaP_0), whereas

Table 2. Honestly significant difference test the effect of different mulches on every level of fertilization on potato tuber Granola amount of land in the plain medium

Treatment	The number of tubers per plot
MoP0	23.7 [a]
MoP1	30.3 [b]
MoP2	**62.0** [c]
MpP0	30.0 [a]
MpP1	32.3 [a]
MpP2	**62.3** [b]
MjP0	30.7 [a]
MjP1	32.0 [b]
MjP2	**63.0** [c]
MaP0	30.7 [a]
MaP1	40.3 [b]
MaP2	**64.3** [c]
HSD 0,01	3,29

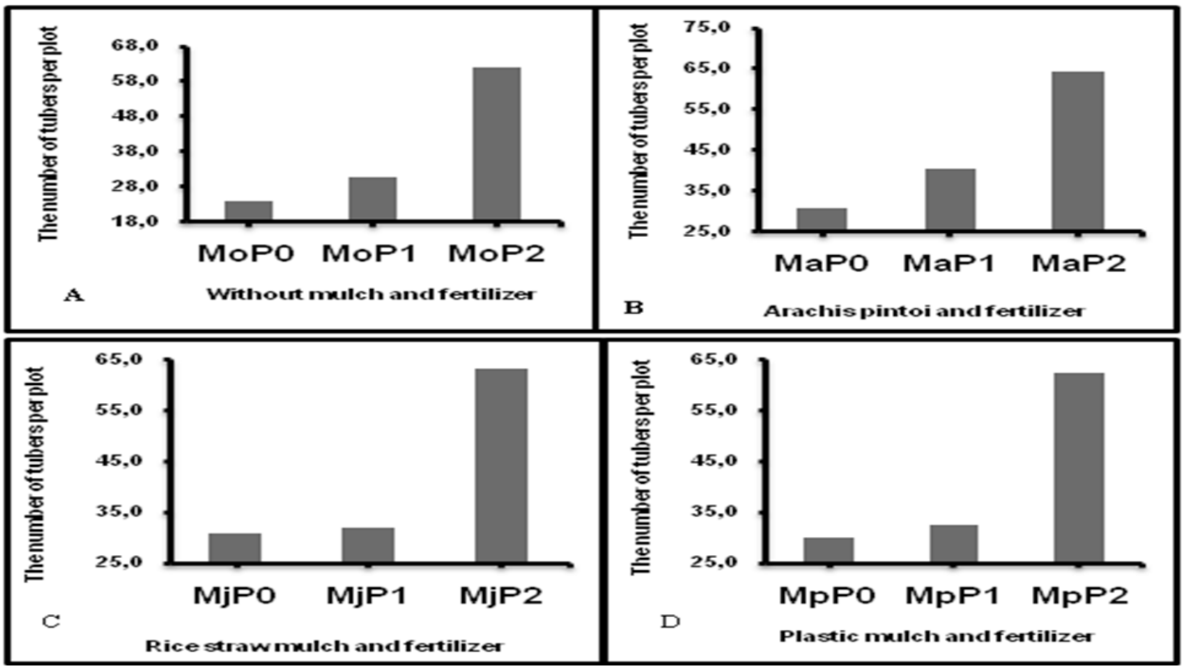

Figure 2. Histogram of the number of potato tubers from each type of mulch at every level of fertilization

treatment of rice straw mulch organic and anorganic fertilizers (M_jP_2) produces the number 63.0 tubers per plot and is highly significant with rice straw mulch treatments and an organic fertilizer alone (MjP_1) and rice straw treatment without fertilizer (MjP_0).

The plastic mulch treatments were given organic and inorganic fertilizers (MpP_2) resulted in the number of tubers per plot of 62.3 and highly significant with plastic mulch treatments given inorganic fertilizer alone (MpP_1) and plastic mulch not given fertilizer (MpP_0). Likewise, treatment with no mulch inorganic fertilizers (MoP_2) produces the number of tubers per plot are 62.0 and highly significant with the treatment without mulch inorganic fertilizers (MoP_1) and treatment without mulch is not given fertilizer (MoP_0). The interaction between type of mulch and fertilizer on the number of tubers per plot are presented in Table 2. Comparison of the average number of tubers per plot of each treatment along with standard values error is shown in Figure 2.

3.3 *Effect of Fertilizer Types on Mulch, Soil Temperature and Number of Bulbs Per Plot*

The results of the analysis showed that the influence of the type of mulch and manure to the night soil temperature resulted in varying temperatures. This turns out to have influence the type of mulch and fertilizer in addition to reduced levels of soil temperature, soil moisture and also increase the formation of potato tubers.

The influence of temperature is generally a limiting factor on the growth and spread of a variety of plants and temperature tolerance of various plants or other organisms (Michael, 1995). Soil temperature changes are ecologically very important for the growth and tuber formation of potato and normal potato plants that live in the highlands above 1,300 m above sea level in environments with low soil temperature of approximately 18 ^{0}C. However, in a plain medium at an altitude of 700 m above sea level, a higher soil temperature of approximately 26 ^{0}C was recorded.

Based on the results, the influence of the type of mulch and fertilizer in general at each measurement could reduce soil temperature that can meet the requirements for the growth and formation of potato tubers. This can be observed at 40 days of potato growth after planting. *Arachis pintoi* treatment with a combination of organic and inorganic fertilizers resulted in the lowest soil temperature of 20.32 ^{0}C when compared with other treatments. *A. pintoi* is capable of lowering the temperature of the ground level by 5.53 ^{0}C. *A. pintoi which can be* general use as a ground cover for the potato crop 40 days after planting may reduce solar heat at ground level and is able to minimize evaporation of potato. *A. pintoi* was able to absorb solar energy and release it if temperature is lower at night. *Arachis pintoi* quickly produce a lower soil temperature and increase soil moisture at night.

Meanwhile, when the potato was covered with rice straw mulch treatment with a combination of organic and inorganic fertilizers 45 days and 50 days after planting, it resulted in the lowest soil temperatures, respectively each at 17.87 ^{0}C and 17.82 ^{0}C. When compared with other treatments and mulch rice straw can lower soil temperature levels each amounted to 6.48 ^{0}C and 6.43

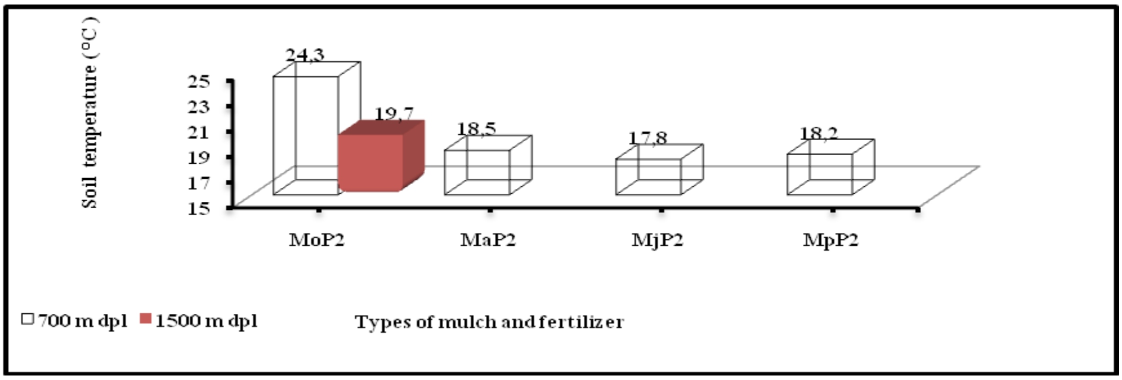

Figure 3. Histogram of the temperature difference at the ground elevation of 700 m - 1500 m above sea level after 50 days of potato planting

^{0}C (Figure 1c). When measurement of soil temperature was taken at 24.00 hours, MoP_2 showed that the treatment resulted in a temperature difference between the ground elevations is 700 m above sea level at the time of the potato crop was 50 days after planting. The soil temperature measurement with the same treatment at an elevation of 1,500 m above sea level was presented in Figure 3.

Treatment without mulch (MoP_2) at an elevation of 700 m above sea level with a temperature of 24.3 ^{0}C generated a higher temperature when compared to the same treatment at an elevation of 1,500 m above sea level with a temperature of 19.7 ^{0}C. The differences in soil temperature is 4.6 ^{0}C. However, if the elevation of planting is 700 m above sea level using similar mulch type of treatment, the soil temperature was lower than at the elevation of 1,500 m above sea level (Figure 2). Figure 2 shows that treatment with a combination of rice straw mulch organic and inorganic fertilizers (MjP_2) produces the lowest soil temperature of 17.82 ^{0}C when compared with other treatments. This implies that rice straw mulch with a combination of organic and anorganic fertilizers can lower the temperature of the soil to a level of 6.4 ^{0}C. The rice straw mulch resulted in lower temperature (1.9 ^{0}C) with a temperature of 19.7 ^{0}C at an elevation of 1500 m above sea level.

The difference in the level of planting elevation of 700 m above sea level compared to an elevation of 1,500 m from sea level may be probably caused by changes in soil temperature. The soil temperature changes depending on the angle of the earth's surface from the sun, the location of latitude, season, altitude, evaporation, clouds, smoke, potato crop canopy or type of mulch used (Lubis, 2007), and the use of mulch and fertilizer will reduce the temperature of the soil (Wenyan *et al*., 2001)

The results of this study support the opinion of Smith (1977) that the soil temperature from 14.9 to 17.7 ^{0}C allows potato tubers to grow well. Furthermore, the bulbs will grow and produce maximum soil temperature of 18 ^{0}C (Hu and Wang, 1985). However, Sunarjono (2007) and Samadi (2010) reported that the optimum soil temperature for the formation of potato tubers was 21^{0}C. Similarly, Setiadi (2009) confirmed that the formation of potato tubers is more suitable with night temperatures of 24 ^{0}C. Meanwhile, according to Janic (1972) and Harlastuti (1980) high soil temperatures reduced the growth production of potato tubers since its dry weight was reduced (Ku *et al*., 1977). Thus, the critical need for the rice straw mulch to reduce soil water evaporation and the plants do not face severe drought (Purwowidodo, 1983).

Similarly, this study indicated that plastic mulch produced a higher temperature effects than the rice straw mulch. This is due to the fact that plastic mulch has no pores for water movement and resulted in the black plastic absorbing more light from the sun. The type of mulch and fertilizer do influence on the number of tubers per plot. Analysis of variance showed that there is an interaction between the type of mulch and fertilizer on potato tuber number per plot and was highly significant, and indicates that the treatment given *A. pintoi* combination of organic and inorganic fertilizer resulted in the highest number of tubers per plot which was 64.3.

A combination of organic and inorganic fertilizers (MAP_2) was able to accelerate the process of growth and more rapid absorbing plant nutrients available for the growth and multiplication of tuber formation. Moreover, because the seeds of plants in a period of rest before adapting to the environment so that the plants grow new seedlings planted must adapt to the new growth environment. This in turn greatly affects the initial growth of the seed potato crop plateau after moved flatness medium (Thomas *et al.* 1993).

Waterlogged sites affect the growth of A. *pintoi* caused by heavy rains that inhibit the growth of A. *pintoi.* Better growth was found to be under a 65% shade. Other than that erosion on agricultural land is estimated at 28 mg/ha/year and the use of plastic mulch to prevent and protect the soil surface from erosion (Kundu *et al*. 2006) were highly recommended.

4. Conclusion

It can be concluded that at an elevation of 700 m above sea level, the rice straw mulch treatment with a combination of organic and inorganic fertilizers resulted in lower soil temperature (17.82 ^{0}C). This implies that rice straw mulch is able to reduce the temperature of the ground level by 6.43 ^{0}C. However, treatment types of mulch are given a combination of organic and anorganic fertilizer resulted in the highest number of tubers. Future work should focus on the use of mulch and fertilizer in getting the optimum growth of potato.

References

1. Anonymous, (2002). Badan Penelitian dan Pengembangan Pertanian,. Kentang Prosesing Untuk agroindustri. Warta 2(24): 1 – 3 (*in Indonesian).*
2. Anonymous, (2007). Badan Pusat Statistik (BPS), Jakarta (*in Indonesian)*.
3. Anonymous, (2009). Hasil Analisis Tanah. Laboratorium Kimia dan Kesuburan Tanah. Jurusan Tanah Fakultas Pertanian. Universitas Hasanuddin. Makassar (*in Indonesian)*.
4. Baharuddin, (2008). Optimalisasi Sistem Produksi Benih Kentang Berbasis Bioteknologi Ramalingkungan. Seminar Pekan Kentang Nasional Dan Tanaman Sayuran. Tanggal 20 – 21 Agustus 2008. Badan Penelitian Dan Pengembangan Pertanian Pusat penelitian Dan Pengembangan Hortikultura Balai Penelitian Penelitian Tanaman Sayuran. Lembang (*in Indonesian)*.

5. Basu, P.S. and J.S. Minhas, (1991). Heat tolerance and assimilate transport in different potato genotypes. J. Exp. Bot. 42(240) : 861 – 866.
6. Burton, W. G. (2004). The Potato Sec. ed. H. Penman and Zonen N. V. Wageningen. Holland. 231 – 2347.
7. Djaenudin (2008). Perkembangan penelitian sumber daya lahan dan kontribusinya untuk mengatasi kebutuhan lahan pertanian di Indonesia. Balai besar penelitian dan pengembangan sumberdaya lahan pertanian Bogor. Jurnal Litbang Pertanian (*in Indonesian)*.
8. Djaenudin (2008). Perkembangan penelitian sumber daya lahan dan kontribusinya untuk mengatasi kebutuhan lahan pertanian di Indonesia. Balai besar penelitian dan pengembangan sumberdaya lahan pertanian Bogor. Jurnal Litbang Pertanian (*in Indonesian)*.
9. Direktorat Jenderal Bina Produksi Hortikultura, (2005). Prospek dan Tantangan Pengembangan Kentang (*in Indonesian)*.
10. Fageria, (1991). Growth and mineral Nutrition of field crops. Marcel Dekker, Inc., New York.
11. Gunarto, A. (2003). Pengaruh penggunaan ukuran bibit terhadap pertumbuhan, produksi dan mutu umbi kentang bibit G4 (*Solanum tuberosum L*.). Jurnal Sains dan Teknologi 5:173-179 (*in Indonesian)*.
12. Harlastuti, (1980). Pemupukan Gandasil D Lewat Daun Dibandingkan Dengan Pemupukan NPK Berat Tanah Pada Tanaman Kentang. Fakultas Pertanian UGM (*in Indonesian)*.
13. Hu, C. Y. and P. J. Wang, (1985). *Potato Tissue Culture and Aplication in Agriculture*. P: 503-577. In Paul H (Ed.). Potato Physiology, Academic Perss, Inc., London.
14. Kundu, P. M., S. S. China, and D. Nyaanga. (2006). Estimating spatial distribution of soil erosion using MUSLE and GIS in Gichobo catchment, Kenya. *J. World Assoc. Soil Water Conserv*. J1: 14-25.
15. Ku, S-B., G.E. Edward, and C.B. Tanner. (1977). Effect of light, carbon dioxide, and temperature on photosynthesis, oxygen inhibition of photosyntesis, and transpiration in *Solanum tuberosum*. *Plant Physiol. 59:868-872.*
16. Laksana, N. (2006). Kebijakan perbenihan kentang Indonesia. Direktur Perbenihan dan Sarana Produksi Hortikultura, Direktorat Jendral Hortikultura. Makalah disampaikan pada Acara Pertemuan Koordinasi Nasional Menuju Swasembada Benih Kentang. Bandung 19 – 21 April 2006 (*in Indonesian)*.
17. Lubis, (2007). Aplikasi Suhu dan Aliran Panas Tanah. Fakultas Pertanian Universitas Sumatra Utara. Medan (*in Indonesian)*.
18. Master, W. A. (2000). *The Economic Impact of Agricultural Research: A Practical Guide*. Department of Agricultural Economic, Purdue University, USA.
19. Purbiati. (2008). Pengaruh umur panen kentang varietas atlantik terhadap hasil dan kualitas di datarn medium. Sumberpucung-Malang. Badan peneitian dan pengembangan pertanian pusat penelitian dan pengembangan hortikultura. Balai penelitian tanaman

sayuran. Lembang – Bandung (*in Indonesian)*.

20. Purwowidodo. (1983). Teknologi Mulsa**.** Dewaruci Press. Jakarta (*in Indonesian)*.
21. Salisbury, F. B and C. W. Ross, (1995). Plant Physiology. Wadsworth Publishing Co. New York.
22. Samadi, (2010). Kentang dan Analisis Usaha Tani. Kanisius. Yogyakarta (*in Indonesian)*.
23. Sarjono, A. (2000). Evaluasi Sifat Fisik dan Kimia Tanah yang Berpengaruh terhadap Pertumbuhan Tegakan Lada di Areal HPHTI PT ITCI Hutani Manunggal. Tesis Magister Program Pascasarjana Ilmu Kehutanan Univer-sitas Mulawarman, Samarinda (*in Indonesian)*.
24. Samadi, B. (2002). Usahatani Kentang. Kanisius, Yogyakarta (*in Indonesian)*.
25. Sarquis, J.I., H. Gonzales, I. Bernal-Lugo. (1996). Response of two potato clones (Solanum tuberosum) to contrasting temperature regimes in the field. Amer. Potato J. 73:285 – 300.
26. Setiadi, (2009). Budidaya Kentang. Penerbit Penebar Swadaya. Jakarta (*in Indonesian)*.
27. Stark, J. C. and S. L. Love, (2003). Potato Production Systems: a comprehenshive guide for potato production. University of Idaho Extension. U.S.A. 426 p.
28. Smith, Q. (1977). Potatoes: production, storing, processing. 2nd ed. The AVI Publ. Co., Inc., Westport, CT.
29. Soelarso, (2008). Budidaya Kentang Berbasis Penyakit. Kanisius, Yogyakarta (*in Indonesian)*.
30. Soemarwoto, (2003). Atur diri sendiri paradigma baru pengelolaan lingkungan hidup. Makalah disampaikan pada Seminar Nasional Manajemen Lingungan.IPB – Bogor. 14 Januari 2003. Bogor (*in Indonesian)*.
31. Thomas, R. S., R. L. Franson, & G. J. Bethlenfalvay. (1993). Separation of VAM Fungus and Root Effects on Soil Agregation. Soil Sci. Am. J., 57: 77-31.
32. Sunarjono, H, H. (2007). Petunjuk Praktis Budidaya Kentang. Agromedia pustaka. Jakarta (*in Indonesian)*.
33. Wattimena, (2006). Prospek Plasma Nutfah kentang dalam Mendukung Swasembada Benih Kentang di Indonesia. Pusat penelitian sumberdaya Hayati dan Bioteknologi (PPSHB) IPB dan Jurusa Agrohort, Fakultas Pertanian. IPB (*in Indonesian).*
34. Wenyan H, Yunwen XU, Qiang L, (2001). Effect of Mulching and Organic Fertilizer on Soil Fertility and the Yield and Quality of Tea In an Organik Conversion Tea Field. Proceedings: The Fifth IFOAM-ASIA Scientific Conference, Oct 31-Nov 4, 2001, Hongzhou, China. 124-129 p.
35. Wicaksana, N. (2001). Penampilan fenotipik beberapa parameter genetic 16 genotip kentang pada lahan sawah di dataran medium. Zuriat 12(1): 15-20 (*in Indonesian)*.

***