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Effects of Row Intercropping System of Corn and Potato and Row Spacing of Corn on the Growth and Yields of Atlantic Potato Cultivar Planted in Medium Altitude

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ABSTRACT

The objective of this research was to study the growth and yield of Atlantic Potato cultivar grown in medium altitude under corn and potato intercropping system and corn row spacing. The experiment was conducted in a research station of Agriculture Faculty of Padjajaran University located in Jatinangor at the altitude of 685 m above sea level with C3 rainfall in Inseptisol soil. It was laid out in Split Plot Design consisting of two factors and four replications. Manipulating growing environment by using corns as shades under different cropping systems was created as the main plot factor which consisted of two cropping systems: 1:1 corn+potato arrangement (one row of corns, one row of potatoes) and 1:2 corn+potato arrangement (one row of corns, two rows of potatoes). The row spacing of corn planted within the rows as the subplots were at 30, 40 and 50 cm. Results of the research indicated that there were no interactions between the corn and potato cropping system and the corn row spacing system over their growth, yields and Land Equivalent Ratio (LER). The plants height of potatoes and their leaf area under 1:1 arrangement were larger compared to those under 1:2 arrangement. On the other hand, the dry mass and the chlorophyll concentrations showed lower value. Although they yield the equal crops, the weight per plot, the yields per hectare and the LER value of 1:1 corns+potatoes cropping system showed higher result. While the row spacing system of corn at 50 cm showed higher value of dry weight, yield per plant, weight per plot and yield per hectare, yet it showed lower value of LER.

Key words: Corn shade, environment manipulation, medium altitude, potatoes

INTRODUCTION

Potato is a type of vegetables which plays more important role either as fresh products or as processed products; an alternative commodity within food diversification. Wider range of potato lands in high altitude areas has caused negative effect to the environment, such as environment damage, due to erosion. For this reason, some alternative ways need to be applied in order to develop the possibility of growing potato in medium altitude areas at 300-700 m above sea level, where can be found in many areas of Indonesia which yields relatively same products and quality. In order to support the industrial/processed potatoes, the qualified and best potato seedlings need to be provided. Engineering potato cultivars resisted to drought and high temperature through mutation is one of the ways to provide potato cultivars which are able to grow in medium altitude areas. In addition, modification research or manipulating environment to create a more suitable

condition for their growing environment in medium altitude areas needs to be done together and is expectedly improving the existed industrial/processed potatoes which have been cultivated by the farmers as in the Atlantic cultivar.

Shading installment on cultivated potatoes in medium altitude areas could reduce both light intensity and high temperature, so this condition has created more suitable environment for potatoes to grow in medium altitude areas. This shading technique applied for growing potatoes in medium altitude has also improved the quality of potato yields.

All growing factors such as temperature, light, soil humidity and the water content could be basically manipulated. Those environment factors interact to each other, for example, temperature and light work together to control plants growth and development. Therefore, temperature should considerably interact not only with the day and night temperature fluctuation but also with the length of the day. Controlling temperature by using shades at the same time has also reduced the light intensity. Manipulating some factors often change other factors (Hamdani, 2013). The success of developing high-altitude plants in medium altitude areas will eventually depend on how far the manipulated growing environment become an ideal environment like the original place needed by the plants or an environment where that kind of plants are usually cultivated.

One of environment-manipulating efforts is controlling the light intensity and reducing the temperature by installing the shades for vegetations or by using paranet and UV plastic shades. According to Treshow (1970), over-intensed light could be reduced by using taller plants as shades, or using certain materials. Yet, it's mentioned that adequate light intensity for plants hadn't been figured out. Hamdani (2013) on potatoes as well as Suradinata *et al.* (2013) study on begonian showed that paranet shading with different shading percentage could cause different micro climate environment within the shades which were shown by the differences of the light intensity, received below the shade; air temperature, soil temperature and humidity. Those conditions have caused different growth with different shading percentage. The taller the shade was growing, the lower air temperature, soil temperature and the light below the shade had become, on the other hand, the humidity had increased. Research on other several plants showed that shading could increase the yields, such as soybeans (Herawati and Salaudin, 1995), mangosteen seedlings (Lukitariati *et al*., 1996).

The study result by Hamdani (2013) showed Indonesia that potatoes planted in medium altitude located in Jatinangor at 650 m above water yielded 630 g per plant. Nevertheless, further study on these cultivars on their yield quality as well as the processed quality need to be developed so they could be grown in medium altitudes, considering processed potatoes would need a more specific modified cultivation. This related to preserving the processing quality of potatoes so that they could produce the expected size with low sugar level (0.5%), starch content (>20%) and their specific height gravity (1.07). Hence, finding out the way to manipulate the environment needs to be done in order to reduce high temperature stress so that the potential productivity could be achieved.

Shading, as artificial shading, can be created by using paranet. A study by Hamdani (2013) showed that using 45% paranet could increase the potatoes growth and yield grown in medium altitude areas. Besides using paranet shading for vegetable plants, plastic shading could also be used. The shading can cause either good and bad effect depends on its purpose. However, using paranet in big scale cost extra budget. Therefore, vegetative shading through multi-cropping system of cultivation or intercropping system with taller plants, like sweet corns, should be experimented further as that system could improve the land productivity, increase the yield as well as the product cost efficiency (Nonnecke, 1989; Yuwariah, 2011).

Modified research or engineered environment, creating a more suitable growing environment in medium altitude by using shading, was adopted by Hamdani (2013) and using many types of shadings, such as paranet, UV plastic and sweet corn-vegetative shading. From the environment observation result on potatoes by Hamdani (2013), it's indicated that the sweet corn-shading could decrease the light intensity, air and soil temperature, yet increase humidity. It also showed that the growth of potatoes processing Atlantic cultivars, grown in medium altitude, such as the plants height and leaf areas didn't show any differences compared to those with paranet and UV plastic shadings. Therefore, the use of shading on potatoes in medium altitude was applied to improve the yields; the qualities of both the yields and processed ones. From the 1st year of observation study (2013); on manipulating growing environment for potatoes, further study on which cropping systems and the row spacing system of corn on the intercropping system of those plants were required. They were important factors to study as the corn vegetative-shading was a lot cheaper, more environmentally friendly, more easily applied and more various yields produced.

Mixed cropping is planting more than one species on the same land, at the same time, or at short interval time. During the application, this twin cropping or intercropping system can be done through strip intercropping and row intercropping. The different way of intercropping system may create competitions among the plants on the growth factors, such as the space, minerals, water and sunlight. Therefore, further study needs to be done in order to know which intercropping system is more suitable for planting potato as the main crop and the corn as the shades. While creating more conducive environment for the main crop; corn as shading, grow well without creating any competitions on the water and minerals needed for both plants. In addition, the conditions such as enough sunlight and low temperature are also fulfilled. The further study on the distance of row-spacing system is also required.

MATERIALS AND METHODS

The experiment was conducted in a research station of Agriculture Faculty of Padjajaran University located in Jatinangor at 685 m above water and C3 rainfall in Inseptisol soil. The experiment was done from Maret 2014 to Juli 2014 applying Split Plot Design. Manipulating growing environment, using corn plants as shades under different cropping systems, was used as the main plot consisting of into two arrangements: 1:1 (one row of corns and one row of potatoes), 1:2 (one row of corns and two rows of potatoes). The row-spacing within the row of corns as the sub-plot consisted of 30, 40 and 50 cm.

Of those two treatments, there were 6 units of treatment with four replications; there were 24 plots treatment. For Land Equivalent Ratio (LER) calculation, corn and potato were planted under sole cropping system within the same size of plot. Determining the plot was done randomly.

After the soil had been processed, the land was arranged into plots with the size, as the treatment required, at 30 cm tall; each plot was divided into 3 seedbeds. The size of the seedbed of 1:1 arrangement was 4 ×1.5 m = 6 m^2; the total size was 18 m^2. There were 26 potato plants within one seedbed under 1:1 arrangement. Meanwhile, the size of the seedbed of 1:2 arrangement was 4×1.2 m = 4.8 m^2; the total size was 14.4 m^2. There were 14 potato plants within one seedbed under 1:2 arrangement. The space of potato within the row was 60×30 cm, while the space of corn, based on the treatment was 30, 40 and 50 cm.

The 20 t ha^{-1} animal manure, recommended by Balitsa (Agriculture Research Center) located in Lembang, Indonesia, was given on both side of the plants. 300 kg ha^{-1} of N fertilizer was given twice: When they were planted and on the 30th day after planting while 100 kg ha^{-1} K

fertilizer and 150 kg ha^{-1} P fertilizer was given at the same time when they were planted. After given fertilizer, the seedbeds were covered by using silver black plastic mulches and then they were holed at 10 cm diameter-size for planting the seeds. The potatoes seeds, from the same generation for each cultivar: the G3 (3rd Generation) with 45-69 g per each grain, were planted into 7.5 cm depth. To avoid insects and other soil pests, 3 g of Furadan were poured around the seeds with the measured weight, 37.5 kg ha^{-1}.

The maintenance stage, including watering the plants, was adjusted to the weather condition. Growing weeds were pulled away and then the soil was piled and hoed and finally fertilized by N fertilizer. Controlling pests and plants diseases was done by spraying Dithane M-45 (a fungicide) and Decis 2.5 EC (an insecticide) with the dose based on the pests intensity. Harvesting was done after the top parts of potato plants, the stems and the leaves, had started to get yellow and fallen out and the skin of the tuber unpeeled.

Environmental observation variable consisted of: (a) Air temperature, humidity, light intensity outside corn plants or in the field, (b) Air temperature, soil temperature, humidity, light intensity either above the potato plants or below the corn plants. The main observation variable consisted of plants height growth variable, leaf area, dry mass and the chlorophyll concentrations at the age of 56 Day after Planting (DAP). The yield variable consisted of the number of potato tuber per plant (g), the yields per plant (g), per bed (kg) and per hectare (t) under the sole-cropping system and the intercropping system of potatoes and corns. Land productivity variable was calculated by applying the Land Balance Ratio (LBR) calculation as follow:

- LBR = yi (yi = yield of the intercropping of plant i)
- Yi (Yi = yield of the sole-cropping of plant i)

RESULTS AND DISCUSSION

Environment condition below the shade: The percentage of ray radiation received by the potato plants below the corn-shading measured during the potatoes growth at each treatment showed significant difference. The percentage of ray radiation on 1:1 arrangement was 67, 81%, below the corn plants on 1:2 arrangement was 74.39%. The average air temperature on 1:1 arrangement was 25.8° while on the 1:2 arrangement was 26.3°; the average soil temperature on 1:1 arrangement was 23.7° while on 1:2 system was 24.1°; the average humidity on 1:1 system was 70.4° while on the 1:2 system was 69.1° (Table 1).

Table 1: Effects of intercropping system of corns and potatoes and row-spacing of corns over the light intensity, air temperature, soil temperature and humidity

Treatments	Average percentage of sun radiation received by potato plants (%)	Average air temperature (°C)	Average soil temperature (°C)	Humidity (%)
Cropping systems				
1:1 corn+potato arrangement	67.81	24.5	23.7	77.2
1:2 corn+potato arrangement	74.39	24.3	24.1	76.2
Row space within corn plants (cm)				
30	65.56	24.1	23.9	77.0
40	67.45	24.2	24.0	76.4
50	73.32	24.4	24.1	76.3

Plants growth

Plants height, leaf area, dry mass and chlorophyll concentrations: Variance analysis result indicated that there were no interactions between the effect of cropping system, planting time, the planting space within the rows of corn plants, on the plants height, leaves width, dry mass and the chlorophyll concentrations (CCI) (Table 2). However, the sole-cropping system of corn and potato has shown significant differences on those factors of potato plants while the row spacing system of corn plant only affected the dry mass of potato plants. The 1:1 corn+potato arrangement has increased the potato height and leaf areas compared to the 1:2 arrangement. Meanwhile, the dry mass and the chlorophyll concentrations of potato plant showed lower value under 1:2 arrangement compared to the 1:1 arrangement. The row spacing system at 50 and 40 cm have significantly increased the dry mass and plants height compared to the row spacing at 30 cm.

Observation result on the environment could be concluded that 1:1 arrangement system and the row spacing system of corn plants at 30 cm has generally caused percentage decline of ray radiation received by potatoes, thus it's resulted in the increase of plants height and leaf area. However, the increase on leaf area did not affect the dry mass due to the wide and thin leaf. Furthermore, the chlorophyll concentrations of the plants applying this treatment were also lower.

At the row intercropping pattern, plants were arranged proportionally with the population per plant components lower than the population under sole-cropping system. One of the plant components associated to the plants can sometimes change the micro climate for other commodities. In this case, the corn plants could change the micro climate of potato plants through the shades which decreased the percentage of ray radiation for potato plants, the air and soil temperature; yet the shades increased the humidity. Shades usually decrease one of intercropped-plants yield as the result of lower percentage of photosynthesis, or cause lay-low growth of the plants. Potatoes under 1:1 arrangement showed taller plants and wider leaf area; yet the plants grew lower due to weak stem. They also displayed etiolation symptoms because the leaf areas were thin yet wide. Consequently, those conditions have caused the plants dry mass become lower. In addition, the chlorophyll concentrations were also lower due to the low reception of ray radiation, compared to the 1:2 arrangement. The average percentage of sun radiation received by potatoes grown below the corns canopy was 67.8%. At a relatively low intensity, the plants tended to stimulate their own height in order to receive adequate sunlight for their physiology process. Gardener *et al.* (1985) stated that etiolation happened to the shaded plants were caused by high production and distribution of auxin which stimulate cell enlargement of plants height. Shades on leaves affected stems elongation and side-bud development of many plants (Salisbury and Ross, 1992). The shaded leaves would receive low percentage of ray radiation.

Table 2: Effects of intercropping system of corns and potatoes and row spacing system of corns over plant height, leaf area, dry mass and chlorophyll concentrations

Treatments	Plant height (cm)	Leaf area (cm^2)	Dry mass (g)	Chlorophyll concentrations (CCI)
Cropping system				
1:1 corn+potatoes arrangement	53.5^b	2474.5^b	7.69^a	26.60^a
1:2 corn+potatoes arrangement	43.2^a	1982.2^a	10.65^b	28.14^b
Row space within the corn plants (cm)				
30	56.7^a	2404.2^a	7.99^a	26.28^a
40	56.5^a	2218.0^a	9.65^b	27.64^a
50	55.7^a	2377.6^a	9.97^b	27.24^a

Average value followed by the same letter do not differ significantly at 5% level according to Duncan's Multiple Range Test (DMRT)

Table 3: Effects of cropping systems and row-spacing system of corn plants over the number of potato tubers per plant and the tuber weight per plant, per plot, per hectare and the LER

Treatments	No. of tuber per plant	Tuber weight per plant (g)	Tuber weight per plot (kg)	Tuber weight per hectare (t)	LER
Cropping systems					
1:1 corn+potato arrangement	7.8[a]	456.7[a]	11.87[b]	15.82[b]	1.60
1:2 corn+potato arrangement	8.1[a]	486.3[a]	6.88[a]	11.46[a]	1.20
Row space within the corn plants (cm)					
30	8.2[a]	385.6[a]	7.70[a]	11.50[a]	1.48
40	8.5[a]	425.8[ab]	8.51[ab]	12.70[ab]	1.40
50	9.0[a]	543.6[b]	9.06[b]	13.50[b]	1.37

Average value followed by the same letter do not differ significantly at 5% level according to Duncan's Multiple Range Test (DMRT)

Height development on shaded plants caused by the increase production of auxin mutually with gibberellin had caused stem elongation. Observation result as seen in Table 3 showed that shading-corn could reduce the light intensity received by potatoes, reduce the air and soil temperature and yet increase humidity. Those results were also stated by Suradinata *et al.* (2013) and Hamdani (2013), optimized light intensity would influence stomata activities to absorb CO_2, the raw material of synthetic carbohydrate and would increase the relative growth pace of potatoes. Weight shading percentage could cause plant to become taller, as plants which required medium to high intensity of sunlight grown in low intensity tended to experience stems elongation (Dan Widiastoety and Bahar, 1995; Prasetyo *et al.*, 2006; Yulianti and Prasetyo, 2007).

Number of potatoes and the weight per plant, the weight per plot, the yield per hectare and the land equivalence ratio: Variance analysis result showed that there were no interactions between the effect of corn+potato cropping systems, the planting time and row-spacing system of corn plants on the number of potato tubers per plant, the tubers weight per plant, the tubers weight per plot dan the tubers weight per hectare (Table 3). However, the sole-cropping system of corn+potato plants has affected the tubers weight per plot and the tubers weight per hectare.

The tubers weight per plants under both cropping systems was not significantly different. On the other hand, the yields per plot and per hectare under 1:1 arrangement were heavier compared to those under 1:2 arrangement. This condition was caused by the population of potatoes under 1:1 arrangement which were higher than the population of 1:2 arrangement. The different population rate on both arrangements did not affect the weight of potatoes per plant.

The effect of different plant species under multi-cropping system has resulted in one species plane that is not affected by others. However, that species can alter the growing environment or the other plants micro climate into either better one or even worse (Yuwariah, 2011).

Row spacing system of corn plant at 50 and 40 cm has significantly increased the potato tubers weight per plant, the tubers weight per plot and the tubers weight per hectare which were different from the 30 cm-row-spaced plants. Hence, it is shown that wide row-spacing was more beneficial for potatoes grown under the intercropping system; they were more tolerant to the shading corns. The row spacing arrangement could cause competitive influence among the same plants, the competition played more important role on multicropped-plants compared to the sole-cropped ones. Environment factors were generally influenced by light intensity and humidity while the light intensity directly affected the photosynthesis process. Wide row-spacing or low population has

caused low competition between the corn and potatoes. Beside that, the plants age were not the same so the intercropped plants required different environment factors. The difference between corns and potatoes were on their root system. Corns had deep root while the potatoes' were the opposite. According to Dachlan (2002), top root could be intercropped with fibrous root where they weren't harming or delaying each other's growth.

Using row-spacing system basically gave adequate space around the plants without causing any competitions. If the row-spacing was over the minimum density, the yield wouldn't be produced optimally. According to experimental study by Marliah *et al.* (2010), it's proven that the row-spacing system on corns had significantly influenced their growth and yields.

The intercropped plants should consist of tall plants which are resistant of high sun intensity and short plants which are sensitive to high sun intensity. Other considerable factor was the shoot system, plants height, plant population and row spacing, family and host plants of different pests. Row spacing affected the plants density and the plant population which caused competition on the sunlight absorption, water and mineral uptake. Asandhi (1988) experiment result concluded that good growing period for intercropped potatoes and cassava was, when the potatoes had been planted two weeks prior than the cassavas. The productivity increased up to 53% within this growing period.

In order to gain maximum crops yield within intercropping system, the plants should be such selected that they can use the space and time efficiently and minimize the competitions factors. The plants used under intercropping system should be the ones which have different growth potential; they even should give mutual benefit (Beets, 1982). The most important thing in intercropping system is to avoid any competitions for the mineral, sunlight and growing space, because when competitions take place the plants growth and productions will be affected.

Overall the land equivalent ratio of 1:1 corn+potato arrangement showed the highest value, at 1.62, or 62% taller compared to the other treatment. It showed that both plants ratio under 1:1 arrangement gained 1.62. Total productivity under intercropping system was at 63% higher. In other words, 62% bigger land was required in order to produce the same amount of yield under both sole-cropping and intercropping system. High value of LER of 1:1 corns+potatoes arrangement was caused by the high plants population, either the corn plants or the potato plants, compared to those of 1:2 arrangement. High population, although the individual yield was low, has increased the crops yield per hectare. This conclusion was based on Al-Dalain (2009), who conducted experiment on corns and potatoes intercropping system and gained 1.43-1.55 LER value. The low LER value of 50 cm-spacing-system was caused by the low population of corns, although produced higher potato yields.

CONCLUSION

- There aren't any interactions between corns+potatoes intercropping system, the planting time and the row spacing over their growth, yield and the LER value
- Potatoes height and their leaf areas applying 1:1 arrangement are higher than the 1:2 arrangement, yet the dry mass and the chlorophyll concentrations are lower. The 1:1 arrangement system of corn+potato has produced equal yields but it's increased the tubers weight per plant, the yield per hectare and the LER value
- Row spacing system within corn plants at 50 cm has increased the potatoes dry mass, yields per plant, weight per plot and yield per hectare but not the LER value

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