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Research Article
Growing Media Compositions and Watering Intervals on Seed Production of Potatoes G2 Grown at Medium Altitude

Wawan Sutari, Sumadi, Anne Nuraini and Jajang Sauman Hamdani

Department of Agronomy, Faculty of Agriculture, University of Padjadjaran, Jalan Raya Bandung, Sumedang km.21, Jatinangor 45363, West Java, Indonesia

Abstract

Background and Objectives: Different compositions of growing media caused different water content, different water retention capacity as well as different watering requirement. Accordingly, accurate watering interval on the growing media of different compositions are expected to increase potatoes' growth and the second generation of potato seed production at medium altitude. This research was conducted to obtain the composition of growing media and the right watering interval for growth and yield of potato G2 Medians cultivar grown at medium altitude. **Materials and Methods:** The experiment was carried out at the research station located in Jatinangor, Indonesia. The experiment was using factorial randomized block design, consisted of three levels of growing media compositions, namely soil+compost+husk charcoal (2:1:1), soil+compost+cocopeat (2:1:1) and soil+compost+cocopeat+husk charcoals (2:1:1:1). They were treated by three levels of watering intervals (once in 2, 3 and 4 days). The potato seed planted is first generation (G1) tuber of potato medians cultivar. **Results:** Results indicated some interactions between growing media compositions and watering interval, affected the rate of stolon percentage and the tubers weight per plant. The compositions of soil+compost+cocopeat (2:1:1) and soil+compost+husk charcoal+cocopeat (2:1:1:1) treated by the watering interval once in 2 days increased the percentage of tuberization (93.33 and 90.86%) and the weight of tubers per plant (335.0 and 355.5 g). As composition of soil+compost+husk charcoal+cocopeat (2:1:1:1) increased the height of plants (58.96 cm), leaf area (5656.44 cm^2), dry weight (50.06 g), Shoot-Root Ratio (7.31) and tubers quantity per plant (13.81 knol). The treatment of once in-two-day watering interval expanded leaf area (4752.72 cm^2) and plants' dry weight (48.17 g). The percentage of seed piece tubers was ranged from 88-94%. **Conclusion:** It was concluded that in Medians cultivar, the use of growing media compositions of soil+compost+cocopeat (2:1:1) and soil+compost+husk charcoal+cocopeat (2:1:1:1) treated by the watering interval once in 2 days increased the percentage of tuberization and the weight of tubers per plant.

Key words: Growing media, tuber of potato, watering intervals, cocopeat, potatoes seed, tuberization, medium land, husk charcoal

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Corresponding Author: Wawan Sutari, Department of Agronomy, Faculty of Agriculture, University of Padjadjaran, Jalan Raya Bandung, Sumedang km.21, Jatinangor 45363, West Java, Indonesia Tel: +62-81-223-57792

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the fourth most important commodity in the world following rice, wheat and corn[1]. In Indonesia, potato is one of vegetable commodities with the highest economical value. It plays an important role both as fresh and processed products. Cultivar medians is a type of potato cultivars grown in Indonesia.

In Indonesia potatoes are mostly cultivated in high altitudes (1000-1300 masl). In order to increase their productivity, expanding the production areas to medium altitudes, which are widely offered in Indonesia, is considered as an affective strategy[2]. On the other hand, growing potatoes in lower altitudes faces several constraints such as high temperature and water shortage[3]. As said by Walker *et al.*[4] one of the efforts to increase the potato product in developing countries is generally implemented by extensification, expanding the area of growing potatoes.

According to Directorate of Horticulture Seeds Ministry of Agriculture of the Republic of Indonesia[5], qualified potato products will depend on the quality of seeds, therefore it need to increase the use of innovative technology in producing the seeds. One of the innovative technology applications for increasing the potato seed of G2 in medium altitude is improving the quality of growing media.

Growing media is one of the most significant factors in supporting potatoes' life and their growth. In addition, it also provides humidity and water supply along with the mineral content carried by media[6]. Proper soil conditions for potatoes should be loosely structured, containing lots of organic matter, fertile, easily binding water and have good drainage[7]. In contrary, solid and in absorbent soil will inhibit growth and tuberization. For that reason, technology modification is necessary to improve soil physical properties by altering the growing media like combining the soil, compost, cocopeat and husk charcoal. Compost is used because of its complete nutrition, both macro and micro, although used in small amount it can increase the growth and the yield of potatoes[8]. Compost, manure, husk charcoal and cocopeat are substantial organic matters in improving growing media properties. Supported by Khanam *et al.*[9] adding manures will increase the organic matters, N Total, provided P factor and Kalium that will be altered in the soil media. Edwards[10] said adding organic matters into the soil can increase the population of microbes, enzyme activities, water retain capacity, pH buffer capacity and the crops yield.

Potato (*Solanum tuberosum* L.) is considered as a drought sensitive crop[1,11], although, each cultivar has its different level of tolerance with drought[11]. As said by Stark *et al.*[12] to reduce the loss of yields and the quality of tubers caused by the drought is by knowing the response of each potato cultivar to the variety of watering in growing seasons. Short water supply affects cell turgor pressure. Turgor pressure is important in many processes of plants, including cell enlargement, gas exchange within the leaf, translocation in phloem and other translocations through the cell membranes[13]. They will certainly be related to the process of tuberizations and their growth. Insufficient water supply can also reduce tubers quantity and their size[14,15].

The longer interval of watering, the lower supply of water found in the soil. The experiment result on red chilly indicated that watering interval of 2 days produces the best chilly[16], while interval of 3 days produces more productive chilly compared to the others[17]. The experiment result by Toyip[18] on water spinach plants shows that applying watering interval of two days affects the numbers of leaf, root volume and its dry weight. Watering interval of 2 days applied to soybean has increased their height[19,20], produced bigger diameter, leaf quantity and leaf area compared to watering intervals of 4, 6 and 8 days[19]. Based on Suhartono *et al.*[20], watering interval of 3 days on soybean plants shows significant changes on their both wet and dry weights.

Different watering intervals applied to different growing media compositions will also cause different condition of the water supply for the plants' growth. Longer interval of watering on the growing media composition with low water retain capacity will cause a faster decrease of water supply, than one with high water retain capacity. For that reason, different composition of growing media will need proper watering interval in order to create a more optimal condition to support the growth and the plant yields. This research was conducted to study about the effect of growing media compositions and the watering intervals on the growth and yields of potato G2 Medians cultivar grown at medium altitude.

MATERIALS AND METHODS

The experiment took place at a research station in Agriculture Faculty of Padjajaran University located in ±685 m above sea level altitude, from September 2016 to March 2017. Inceptisols soil from Jatinangor was used for this experiment.

The experiment was applying factorial randomized block design consisted of two factors. The first one consisted of the growing media compositions of soil+compost+husk charcoal (2:1:1), soil+compost+cocopeat (2:1:1) and soil+compost+husk charcoal+cocopeat (2:1:1:1). The second one was the

watering intervals of 2, 3 and 4 days. There were 9 treatments with 3 replications on each until 27 units of experiment were gained. Every unit consisted of ten vegetations planted inside provided poly bags, so there were finally 270 experimental plants. The growing media, with each composition and watering interval treatment was set a poly bag of 50×50 cm.

Seeds of G1 potato Medians cultivars were planted in ±7.5 cm depth and then covered with soil. They were given urea inorganic fertilizers at the dosage of 300 kg ha^{-1} (6.85 g $plant^{-1}$), SP-36 of 200 kg ha^{-1} (3.42 g $plant^{-1}$) and KCl of 150 kg ha^{-1} (3.49 g $plant^{-1}$). The space of each plants were 50×50 cm. Plants maintenance including watering, weeding, ridging and pests control were carried out in order to keep the plants straight up. Watering applications are carried out in accordance with each watering interval treatment, until the growing media reaches field capacity conditions. Harvesting started when the potatoes were well-ripened, leaves became yellowish, the bark was firm enough to be unscratched.

Observation and data collection: The physical properties of each growing media composition were analyzed before planting[21], consisted of:

- $\text{Media density (kg L}^{-1}) = \frac{\text{Media weight (kg)}}{\text{Media volume (L)}}$
- $\text{Porosity (\%)} = \frac{\text{Water volume (L)}}{\text{Growing media volume (L)}} \times 100\%$
- $\text{Air space (\%)} = \frac{\text{Water gravity volume (L)}}{\text{Growing media volume (L)}} \times 100\%$
- Water retain capacity (%) = Porosity (%) air space (%)

Variable observations of potatoes' growth and their tubers production covered Leaf Relative Water Content (LRWC)[2], proline content (µmoles g^{-1}), chlorophyll content index, plants height (cm), leaf area (cm^2), dry weight (g), Shoot-Root Ratio (SRR), Stolon Tuberization (%), number of tubers per plant (knol), tubers weight per plant (g) and seed piece tubers quantity (%). Observation on plant height, LRWC, proline content, chlorophyll content, leaf area, dry weight and SRR were carried out at the end of tuber initiation, i.e., at 8 weeks after planting[22]. The number of sample plants observed in each experimental unit was three plants.

Plant height measured from the surface of media till the tip of meristem apical. The chlorophyll content is counted by using Chlorophyll meter. Proline content is measured by Ninhydrin method[23]. Leaf area was measured using Gravimetric[24]. The roots and shoots portion were dried in an oven until they reach a constant weight, then weighed to obtain data on plant dry weight and SRR. The tubers were harvested, counted and weighed to determine number of tuber, tubers weight and percentage of seed piece tubers quantity.

Data analysis: The data obtained were analyzed statistically using Two-ways analysis of variance by F-Test on 5% significance level to determine the effect of treatment. If the treatment shows effect significantly, further testing was carried out using the Duncan's Multiple Range Test (DMRT) on 5% significance level to compare the mean values between treatments[25].

RESULTS

Growing media physical properties: Based on the analytical result on physical properties of the growing media, it's shown that media composition of soil+compost+husk charcoal+cocopeat (2:1:1:1) has lower density compared to the others (Table 1). The highest percentage of porosity and air space are found in the composition of soil+compost+husk charcoal (2:1:1) with each rates at 62.5 and 23%, in addition the media composition of soil+compost+husk charcoal+cocopeat (2:1:1:1) each rates at 62.0 and 20.0%. The media composition with high percentage of its porosity and air space will finely facilitate the root growth and its respiration process.

Leaf relative water content (LRWC), proline content and chlorophyll content: Leaf Relative Water Content (LRWC) and proline content on the plants were showed the plants' response to water shortage condition in the growing media. The composed media of soil+compost+cocopeat (2:1:1) has higher value of LRWC than other media. Watering interval of two days showed higher rate on LRWC percentage than those with the 3 day and four-day watering intervals. High content of proline is found in each composition of soil+compost+husk charcoal (2:1:1) with treatment 4 day-watering interval. Whereas high content of chlorophyll is found in the composition of soil+compost+cocopeat (2:1:1) treated with 2 day-watering interval (Table 2).

Plants height, leaf area, dry weight and shoot-root ratio: Analytical statistic results showed no interactions between media compositions and the watering intervals on plants height, leaf area, dry weight and shoot-root ratio. Different

Table 1: Growing media physical properties

Growing media compositions	Bulk density of growing media (kg L^{-1})	Porosity (%)	Air space (%)	Water retain capacity (%)
Soil+compost+husk charcoals (2:1:1)	0.73	62.5	23.0	17.0
Soil+compost+cocopeat (2:1:1)	0.70	58.5	18.0	22.0
Soil+compost+husk charcoals+cocopeat (2:1:1:1)	0.62	62.0	20.0	15.5

Table 2: Watering interval effects on leaf relative water content (LRWC), proline and chlorophyll content index

Treatments	Leaf relative water content (LRWC) (%)	Proline content (μMoles g^{-1})	Chlorophyll content index
Growing media			
Soil+compost+husk charcoal (2:1:1)	52.28	0.157	23.47
Soil+compost+cocopeat (2:1:1)	64.24	0.123	26.74
Soil+compost+husk charcoal+cocopeat (2:1:1:1)	53.98	0.142	23.45
Watering intervals			
In 2 days	62.73	0.174	26.46
In 3 days	55.32	0.189	24.86
In 4 days	52.02	0.198	24.74

Table 3: Effect of media composition and watering intervals on plants' height, leaf area, dry weights and shoot-root ratio

Treatments	Plants height (cm)	Leaf area (cm^2)	Dry weight (g)	Shoot-root ratio
Growing media compositions				
Soil+compost+husk charcoal (2:1:1)	48.22^{a}	4016.78^{a}	43.24^{a}	6.31^{a}
Soil+compost+cocopeat(2:1:1)	57.16^{b}	4042.31^{a}	44.95^{a}	6.12^{a}
Soil+compost+husk charcoal+cocopeat (2:1:1:1)	58.96^{b}	5656.44^{b}	50.06^{b}	7.31^{b}
Watering intervals				
In 2 days	50.71^{a}	4752.72^{b}	48.17^{b}	6.21^{a}
In 3 days	51.17^{a}	4403.18^{a}	$46.15a^{ab}$	6.56^{a}
In 4 days	51.46^{a}	3559.63^{a}	36.04^{a}	6.97^{a}

Average rates followed by same letters in the same column are insignificantly different according to Duncan multiple range test level at 5%

Table 4: Effect of interactions between media compositions and watering intervals stolon tuberization (%)

	Watering intervals (I)		
Media (M)	2 days	3 days	4 days
Soil+compost+husk charcoals (2:1:1)	86.33^{aC}	76.46^{aB}	54.23^{aA}
Soil+compost+cocopeat((2:1:1)	93.33^{bC}	84.08^{bB}	64.87^{bA}
Soil+compost+husk charcoals+cocopeat (2:1:1:1)	90.86^{bC}	81.66^{bB}	75.88^{cA}

Average rates followed by same letters in the same column are insignificantly different according to Duncan multiple range test level at 5%. Small case letters are red vertically and capital letters are read horizontally

media compositions affect those variables significantly and highest values observed in soil+compost+husk charcoal+ cocopeat (2:1:1:1). While, watering interval treatments do not cause significant difference on either the plant's heights or shoot-root ratio (Table 3).

Stolon tuberization (%): Analytical statistic result indicated no interactions between growing media compositions and watering intervals on the percentage of stolon tuberization (Table 4). Using media composition of soil+ compost+cocopeat (2:1:1) and media of soil+compost+ husk charcoals+cocopeat (2:1:1:1) with 2-day watering interval shows high percentage of stolon tuberization.

Tubers weight, number of tubers and the percentage of seedpiece tubers: Analytic result demonstrates interactions between composed growing media and watering intervals on the tubers weight (Table 5). Using media of soil+compost+husk charcoal+cocopeat (2:1:1:1) with watering interval of 2 days, along with the treatment of soil+compost+husk charcoal (2:1:1) with watering interval of 3 days have resulted in increased tubers weight. Watering intervals of 2, 3 and 4 days have led to insignificantly different tubers weight in the media of soil+compost+ cocopeat (2:1:1).

Growing media composition and watering intervals showed no effects on the tubers quantity and the seedpiece tubers percentage (Table 6). Whereas, treatment of media composition of soil+compost+husk charcoals+cocopeat (2:1:1:1) produces the highest tubers quantity per plant (13.81 knol).

Table 5: Effect of composed media and watering intervals interaction on the tubers weight per plant (g)

	Watering intervals (I)		
Media (M)	2 days	3 days	4 days
Soil+compost+Husk charcoals (2:1:1)	156.4^{aA}	330.8^{bC}	225.0^{bB}
Soil+compost+cocopeat (2:1:1)	335.0^{bA}	328.7^{bA}	328.9^{aA}
Soil+compost+husk charcoals+cocopeat(2:1:1:1)	355.5^{bC}	158.2^{aB}	289.8^{cA}

Average rates followed by same letters in the same column are insignificantly different according to Duncan multiple range test level at 5%. Small case letters are red vertically and capital letters are read horizontally

Table 6: Effects of interactions between media compositions and watering intervals on tubers quantity and percentage of seed piece tubers per plant

Treatments	Tubers quantity (knol)	Tubers seed piece (%)
Growing media compositions		
soil+compost+husk charcoals (2:1:1)	10.30^{a}	94.25^{a}
soil+compost+cocopeat (2:1:1)	11.80^{a}	89.24^{a}
soil+compost+husk charcoals+cocopeat (2:1:1:1)	13.81^{b}	88.38^{a}
Watering intervals		
In 2days	12.26^{a}	88.59^{a}
In 3 days	12.31^{a}	87.72^{a}
In 4 days	12.33^{a}	90.90^{a}

Average rates followed by same letters in the same column are insignificantly different according to Duncan multiple range test level at 5%

DISCUSSION

The composition of growing media of soil+compost+ cocopeat (2:1:1) has water retention capacity higher than growing media composition of soil+compost+husk charcoals (2:1:1) and soil+compost+husk charcoals+cocopeat (2:1:1:1). Therefore, it enables media to keep water. However, keeping the media from being over-moist should be as well concerned. Porous media contained empty spaces among the materials to allow the air circulate well. On the other side, it's unable to retain enough water.

Growing media composition with high water retention capacity manages to supply enough water for an optimal photosynthesis process. In addition, that condition is also supported by an optimal porosity of the media to help tubers growth and tuberizations process. Tuberizations consist of stolon formation followed by tubers formation from the stolon tips. Some factors which can affect stolon formations are apical buds, darkness, humidity and growth hormones[26].

Growing media composition of soil+compost+husk charcoals (2:1:1) and soil+compost+husk charcoals+ cocopeat (2:1:1:1) are media with good porosity and good water retention capacity. Good water retention capacity will make the plant to have enough water supply and to bind nutrients possible. While, good porosity supports root growth and stolon formation. If the water retention capacity is low, photosynthate of the plants will be affected, then it will cause root growth and stolon formation to become less optimal.

Growing media composition of soil+compost+ cocopeat (2:1:1) has produced Leaf Relative Water Content (LRWC) of potatoes higher than by other media. This condition was related to the ability of the plant to retain water higher due to the compost and cocopeat elements, resulting in enough water supply. LRWC rate has been decreased due to longer watering interval. On the other hand, watering interval of 2 days has created higher LRWC compared to those with interval of 3 and 4 days. Results indicated that watering interval of 2 days has given enough water supply for the crops development.

Protatoes planted by using media of soil+compost+ cocopeat (2:1:1) showed low proline content. Furthermore, it's been found out that reducing the amount of water will affect the proline content in the crops. Less watering will lead to some high proline content, watering interval of 4 days indicates the highest proline content. Proline is an important substance for osmotic stress and will be accumulated when the crops are having water deficit. Proline found in some plants with low water supply is synthesized as the cell osmotic flow effect by increasing dissolve compound within the cells, so intra osmotic cell is lower or at least equal to surrounded media. This supports the research by Umebese *et al.*[27] on spinach and tomatoes.

Chlorophyll content found in potatoes with the media of soil+compost+cocoppeat (2:1:1) was higher than other media. This condition was related to the crop's high capacity to retain water. The content decreased as low frequency of watering, treatment of 2 day-watering interval showed higher chlorophyll content compared to the 3 and 4 day-ones.

Using growing media composed of soil+compost+husk charcoals+cocopeat (2:1:1:1) has produced taller plants, wider leaf area dan higher value of shoot-root ratio than by using

other media. Whereas plants' height variable using media of soil+compost+husk charcoals+cocopeat (2:1:1:1) isn't different from using the media of soil+compost+cocopeat (2:1:1). The condition of those media are affected by water supply, nutrients and root growth. Agustin *et al.*[28] said that a good system of root growth will influence the crop's canopy growth, covering height and stems diameter. Root transfers nutrients and water from the media to the canopy for photosynthesis, while the canopy provides the photosynthesis products beneficial for the roots growth and other parts of the plant.

Enough amount of nutrients within the soil will support normal plants growth. As said by Zelalem *et al.*[29] that it affects the plants height to grow better. According to Andri *et al.*[30], it's found out that adding 50 g compost of empty bunch oil palm and 50 g cocopeat per plant may improve chemical properties because it can increase nutrient availability and nutrient uptake by plant roots, it will also improve soil physical properties such as soil structure improvement, water storage and soil aeration. These elements help plants grow better.

Potatoes grow better using media of soil+compost+husk charcoals+cocopeat (2:1:1:1). It showed that the materials needed for photosynthesis and photosynthate translocation process are provided well. It has also resulted in better tubers yield as shown in the tubers quantity per plant (13.81 knol) which is higher than potatoes planted in other media. Nevertheless, growing media doesn't affect the percentage of seed piece tubers significantly.

Watering interval of two days has produced wider leaf area and higher dry weight. Watering interval determines water supply for the plant's growth and yield. One of the reasons why potatoes are sensitive to drought is their rather shallows rooting system[31,32], this also describes physiological responses of the plants to the water shortage.

Watering interval will also affect tuberization process. Tuberization is closely connected to stolon formation and tubers formation at the stolon tips. However, not every stolon can form tubers[27]. According to Olle *et al.*[33], fine growing media is the one that can provide enough amount of water and nutrients, accommodates air circulation within root and atmosphere above the media and supports the plant's growth. Tuberization is influenced by two factors: internal and environmental. Internal factors includes growth hormones and carbohydrates metabolism, whereas external factors are length of days, temperature, humidity and nutrients.

Tubers were formed from extended stolon in the soil as ascending stolon reaching the surface creates new shoot. Generally, tuberization process has been affected by length of day, temperature, reserves of photosynthesis and cultivars[11,12,34]. High dry weight depends on the crops growth. The better growth of potatoes, the higher yields they produce. The weight of tuber per plant was determined by assimilate translocated and is kept as food reserves. Low quantity of assimilate will result in low tuber weight or vice versa[25]. Other factor causing low tubers yield is there's greater respiration than photosynthesis activity, therefore translocation of photosynthate climb down to the tubers, yet it goes up to the leaves and stems[35].

The research showed that using growing media composed of soil+compost+cocopeat (2:1:1) and media of soil+compost+husk charcoals+cocopeat (2:1:1:1) treated with once in two days watering interval managed to produce high percentage of tuberization by the stolon. The use of composition growing media composed soil+compost+husk charcoals+cocopeat (2:1:1:1) with watering interval 2 days can produce high potato tuber weights.

CONCLUSION

There are some effects of interactions between growing media compositions and watering intervals on the percentage of tuberization by stolons and tubers weight per plant. Growing media composed of soil+compost+cocopeat (2:1:1) and media composed of soil+compost+husk charcoals+cocopeat (2:1:1:1) with watering interval of two days can increase the percentage of tuberizations by stolon respectively at 93.33 and 90.86%, they also improve the tubers weight per plant up to 335.0 and 355.5 g, respectively. Meanwhile, the number of seed pieces tubers that can be produced ranges from 88-94% of totals number tubers per plant.

Application of once in two days watering interval produce leaf area and dry weight of plants was higher. The using of compositions of the growing media composed of soil+compost+husk charcoal+cocopeat (2:1:1:1) resulted in plant height, plant dry weight, shoot-root ratio and numbers of tubers per plant were higher.

SIGNIFICANCE STATEMENT

Plant growth and yield of potato in medium altitude of Indonesia are reduced because of quality of growing media beside of high temperature. The media can affect not only root growth but also the stolon formation, along with the process of stolon becomes tuber. To increase the potatoes' tuber, therefore, some environmental modification are needed to improved of growing media and water content. Accurate interval watering on the growing media of different compositions significantly increase potatoes' growth and their seeds production in medium land of Indonesia.

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