The effect of pruning type on old seedling of chili pepper (Capsicum annuum L.) plants to the growth and yield

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Abstract. This research aimed to determine the effect of the pruning type to old seedling of chili plants to the growth and yield. The research was conducted from April until August 2019 at Syiah Kuala District, Banda Aceh. The research was designed as a non-factorial randomized block design with four levels of treatment and six replications. There were 72 units of polybags of research. Pruning types consist of four levels, namely control (no pruning), shoot pruning, root pruning, and combination of shoot and root pruning. The result indicates that pruning type had a very significant effect on plant height, stem diameter, number of fruit per plant, each fruit weight, weight of fruit per plant, and plant productivity, it also indicates a significant effect on the length of fruit. Better growth and yield of chili pepper are found in root pruned plant and control. The high fruit length and each fruit weight are found in shoot pruned and the combination of shoot and root pruned plant. The highest number of productive branches and diameter of fruit are found in combination of shoot and root pruned plant. The lowest percentage of virus symptomatic plants and early flowering is found in the control.

1. Introduction
Capsicum is one of the most important spices used worldwide as it accumulates pungent capsaicin in its fruits [1]. Chili pepper (Capsicum annuum L.) is a horticulture commodity and a source of income for vegetable farmer in Indonesia, with the production occupying at least 155,000 ha and involving more than 500,000 farmers in the country [2], [3]. Chili pepper is a non-oil and gas export commodity [4]. The demand for chili is currently increasing in both domestic and export markets [5].

According to The Ministry of Agriculture of The Republic of Indonesia (2020), chili pepper production in Indonesia from 2018 to 2019 increased from 1,206,737 tons to 1,214,419 tons (growth 0.64%). The chili pepper productivity in Indonesia has also increased from 2018 to 2019, which is 8.77 tons ha⁻¹ to 9.10 tons ha⁻¹. However, in Aceh province, the chili pepper production from 2018 to 2019 decreased from 68,151 tons to 63,595 tons (growth -6.69%). The decrease in chili production was caused by a decrease in productivity. Chili pepper productivity in Aceh province in 2018 to 2019 decreased from 13.91 tons ha⁻¹ to 13.09 tons ha⁻¹. In Indonesia chili pepper production and productivity had fluctuation depend on the location of cultivation. The average national chili pepper productivity is 6 tons ha⁻¹. [6] reports that the potential productivity of chili paper can reach 20-40 ton ha⁻¹, however, currently it is difficult to reach this production potential, so it is difficult to find large quantities of chili pepper in the market according to the amount needed.
The chili productivity reduction has leaded the chili prices to the escalation domestically. The low production of chili is induced by the lack of innovation in applied cultivation technology and the presences of pest and disease in the chili plants one of which virus infection. The improvement of cultivation techniques is required, therefore the production of chili plants is able to be increased. The improvement of cultivation techniques is able to be started from the selection of adaptable varieties and maintenance measures, such as nursery techniques [7].

The concerned chili nursery technique is the seedling. [8] stated that generally chili seedlings are remain in nurseries until they are 15-17 days old or after 3 to 4 leaves sprouted, after which, it is able to be transplanted. In some certain land conditions, it is not allowing it to be transplanted, causing chili seedlings remain in the nursery and late for transplanting, thus the age of the chili seedlings has reached old age of more than 30 days. Farmers generally assumed that the age of old chili seedling (more than 30 days) cannot produced optimal chili production, therefore farmers choosed to discard or not using the chili seedlings. One of the reuse technique of old chili seedlings is by pruning, which consists of two types, shoot and root pruning.

Pruning is the act of removing part of the plant with the intention of growing or stimulating flowering and fruiting in the desired direction, or increase the efficiency of nutrient used [7]. The shoot pruning on curly red chili could increase the number of productive branches and the number of flowers and emerging fruit [9]. The large number of branches induced more number of leaves thus the process of photosynthesis increased and the formation of new flowers induced [10]. Pruning the shoots at the time of the seedlings is also able to increase the production of chili plants [11].

Besides shoots pruning, the utilization of old chili pepper seedlings can also be implemented by root pruning. Pruning the roots can increase growth and yield in chili pepper plants, because the nutrients are absorbed by the roots directly distributed to the leaves as the plant so the plant stems will form a strong and upright [12]. The root pruning was observed to induce the accumulation of auxin hormone in the pruned lateral root thus it stimulates the formation of new branching roots. Zakaria et al. (2020) state that restricted root growth could cause a organs. Root restriction caused an alteration of the sink strength of roots and ultimately, the source and sink relationship of the whole plants.

Pruning chili pepper, usually making plants so vulnerable to disease, such as viruses. One symptom reduction of the sink capacity in the sink of a virus infected plant is generally indicated by the stunted growth and yellowing leaves. Pruning shoots on chili pepper can accelerate infection with viral gemini disease, one of which is begomovirus carried by whitefly. Begomovirus transmitted by whitefly is a serious obstacle in the cultivation of various vegetable plants in Aceh province [13]. Viral infection causes a decrease in chili pepper growth and yield thus production is almost entirely lost if the plant is infected earlier [14]. Therefore, it should be noted that the percentage of plants affected by viruses different from shoot pruning and root pruning. Pruned shoots can be infected by pest and disease easily. Falling over sprout is one of the common diseases that often infects plants in the nursery phase where the tissue is still succulent. This sprout disease caused by Pythium sp. is a disease that often causes losses to plants. It causes plants to wither and wet root rot, in addition, the leaves or shoots can be infected with brown rot symptoms [15]. Based on the description above, it is required to analyze the effect of pruning types on the old seedling of chili pepper plants to the growth and yield.

2. Materials and methods
2.1. Materials and grow conditions
The research was conducted in the Gampong Pineung community land, Syiah Kuala District, Banda Aceh. The research started from April until August 2019. The tools used in this study were five nursery trays (55 cm x width 28 cm x 5 cm depth), scissors, hoe, shovel, hand sprayer, meter ribbon, watering can, water hose, digital scales, and camera. The materials were Perintis (the local cultivar from Aceh), fungicides (active ingredient: Mancozeb) 1 ml L⁻¹, top soil, compost, rice husk, NPK Mutiara fertilizer (16:16:16), Bio In Grow fertilizer, insecticide (active ingredient: Diafentiuron), 10 kg polybags (diameter 35 cm x length 40 cm), alcohol 90% and bamboo stakes.
The chili pepper seeds treatment were conducted by soaking the seeds in warm water (50°C) for 3 minutes to break dormancy, then the seeds are cured by wrapping in a damp cloth for 24 hours. Seeds are then sown in a tray of 1:1 topsoil and compost combination for 35 days under the shade. After 35 days of sowing, the seedlings were then selected for the pruning. Chili pepper seeds are selected that grow healthy. The characteristics of healthy seedlings are, contain 6-8 leaves, trunked sturdy, green leaves and stems.

2.2. Pruning method
There were three types of pruning implemented in the chili pepper. Shoot pruning, root pruning, the combination of shoot and root pruning. The planting media used are mixed of top soil, compost and rice husk with a volume ratio (1: 1: 1). The mixed media was putting into polybag. The shoot pruning was implemented by pruning the tip of the stem 3 cm from the top using sterilized scissors, then transplanted into polybags. Whereas, the root pruning was implemented by removing the remaining soils on the seedling roots by driping it into the water and pruning 3 cm length from the tip of root. After the root pruning was done, the seedlings roots then soaked in fungicide solution (active ingredient: Mancozeb, as much as 1 ml L⁻¹ water) for a minute in order to sterilize the roots, then transplanted. The control plants without no pruning treatment were normally transplanted.

2.3. Transplantation and cultivation
The pruned chili pepper seedling after transplanted into polybags, then located in under the shade for a week. After a week, the plants were placed under the open field. The fertilization was applied started from the 3 days post transplantation (dpt) by applying NPK Mutiara fertilizer and at 8 dpt by applying Bio In Grow. NPK Mutiara Fertilizer is given once every 10 days as much as 200 ml per polybag. Fertilizer solution is made by dissolved NPK Mutiara as much as 20 g L⁻¹ water. Bio In Grow fertilizer applied is by dissolving it as much as 2 ml L⁻¹ water. This fertilizer is done by spraying the leaves of chili pepper plants starting at the age of 8 dpt and given once every 10 days. The pest and diseases management was done by applying chemical pesticides. Giving insecticides (active ingredients: Diafentiuron) is done by spraying the leaves of chili plants in the afternoon and given once every 10 days. Insecticide dissolved as much as 2 ml L⁻¹ water. For the harvest period, spraying of insecticides is carried out after harvesting takes place to avoid the fruit being exposed to insecticides. The weeds management were conducted mechanically by manually pulling out the weeds. The chili paper harvesting were started at 75 dpt.

Chili paper plants were supported by tying it to the bamboo stakes at 7 dpt. The application of organic rice husk mulch is conducted at the same day. Rice husk is applied to the surface of the soil with 2 cm thick polybag to reduce evaporation and to be functioned as natural mulch.

2.4. Growth and yield parameter
The parameters for the growth are plant height (cm), stem diameter (cm), number of productive branches and the flowering day (days). Whereas for the yield are number of fruits per plant, fruit length (cm), fruit diameter (cm), each fruit weight (g), fruit weight per plant (g), productivity (ton ha⁻¹), and the disease incidence of viral symptomatic plants (%). The harvest was carried out 10 times.

2.4.1. Productivity
The value of productivity from each treatments is obtained using the equation below:

\[
\text{Productivity (tons ha}^{-1}) = \frac{1 \text{ Hectare} - 20\%}{\text{each plants distance}} \times \text{Total fruit weight per plant}
\]  

(1)

2.4.2. Viral disease incidence
In accordance to evaluate the percentage of plants infected by virus and indicating symptoms, the following equation is used:
4

\[ \text{DI} (\%) = \frac{n}{N} \times 100 \]  
(2)

Where,

\( \text{DI} \)  = Disease incidence caused by virus
\( n \)  = number of virus symptomatic plants
\( N \)  = number of surveyed plants

2.3 Data Analysis

Statistical analysis of variance (ANOVA) using Microsoft excel window 10. The difference between varieties were determined by least significant different (LSD) \( P < 0.05 \) to determine statistically significant differences.

3. Results and discussion

3.1. Effect of pruning type on the growth of old seedling of chili papper

The results of the analysis of variance indicates that the pruning type has a very significant effect on plant height and stem diameter, yet has no significant effect to number of productive branches. The growth of plant height, stem diameter, number of productive branches and flowering age in several pruning types can be seen in Table 1.

Table 1 indicates that higher chili pepper plants at the age of 15, 30, 45 and 60 dpt were found in control and root pruning, which were significantly different from shoot pruning and combination of shoot and root pruning. The control treatment has a higher plant since the apical dominance occured thus growth is only focused on the apical shoots and the auxin hormone in the bud capable of working optimally. This is in accordance with the research of Tjitra et al. (2018), ornamental chili plants without any shoot pruning treatment had higher plant height compared to plants treated with shoot pruning. In *G. gnemon* seedlings, root pruning provides better plant height growth. This is because root pruning can increase the growth of the number of root branches so that the volume of roots formed can help the absorption of nutrients better [16].

Larger stem diameters at 15, 30, 45 and 60 dpt are found in control and root pruning, which is significantly different from shoot pruning and combination of shoot and root pruning. This may be due to root pruning, roots that have been pruned will emerge new lateral roots thus the process of nutrient extraction in the soil capable of working optimally which will be used to enlarge the diameter circle of plant stems. This was explained in the study of [17] that root pruning is able to stimulate lateral root growth in seedlings, and the new lateral roots formed help the seedlings in absorption of nutrients used for the growth of its seedlings and root development. [18] stated that plants need root pruning for seedling production, in order to be able to stimulate a dense and compact root system so that the root shoot ratio is high, limiting the root system too deep, avoiding root problems that will be encountered later in life such as roots wrapped around and bent roots in a container, and limits the rate of growth of shoots for plants that grow too fast.

The number of productive branches at the age of 15 dpt tends to be more found in root pruning, but at the age of 30, 45 and 60 dpt the number of productive branches that tend to be more found in shoots and roots pruning eventhough statistically shows no significant difference with other treatments. This is because pruning can stop apical dominance, therefore triggering the growth of new branches. The effect of shoot pruning on curly red chili plants had a higher number of branches [9]. This is because shoots pruning in the seedlings will reduce apical dominance which will stimulate the hormone auxin to grow lateral buds or branch buds [19]. In addition, root pruning is also able to encourage the growth of the number of chilli branches. Root pruning can reduced the concentration of the cytokinin hormone which causes the transport of auxin hormone from the apical meristem to the roots run smoothly so that it stimulates lateral root growth [20]. Auxin hormone and cytokinin will help plants in the process of restoring balance between shoots and roots after root pruning activities [21].
Table 1. Average growth of plant height, stem diameter, number of productive branches, and flowering age in several pruning types on old seedling of chilli pepper.

| Parameters                              | Control | Shoot pruning | Root pruning | Shoot and roots pruning | LSD_{0.05} |
|-----------------------------------------|---------|---------------|--------------|--------------------------|------------|
| Plant height (cm) 15 dpt                | 64.5 b  | 38.4 a        | 57.9 b       | 36.6 a                   | 3.69       |
| Plant height (cm) 30 dpt                | 78.3 b  | 53.1 a        | 75.0 b       | 52.6 a                   | 4.27       |
| Plant height (cm) 45 dpt                | 87.6 b  | 74.8 a        | 86.1 b       | 77.9 a                   | 5.64       |
| Plant height (cm) 60 dpt                | 91.1 b  | 81.0 a        | 90.4 b       | 81.7 a                   | 5.40       |
| Stem diameter (cm) 15 dpt               | 0.37 b  | 0.34 a        | 0.38 b       | 0.33 a                   | 0.02       |
| Stem diameter (cm) 30 dpt               | 0.53 b  | 0.41 a        | 0.52 b       | 0.41 a                   | 0.02       |
| Stem diameter (cm) 45 dpt               | 0.58 b  | 0.48 a        | 0.56 b       | 0.47 a                   | 0.03       |
| Stem diameter (cm) 60 dpt               | 0.65 b  | 0.55 a        | 0.62 b       | 0.54 a                   | 0.03       |
| Number of productive branches (branches) 15 dpt | 1.42    | 1.47          | 1.67         | 1.31                     | -          |
| Number of productive branches (branches) 30 dpt | 2.17    | 2.00          | 1.94         | 2.33                     | -          |
| Number of productive branches (branches) 45 dpt | 3.39    | 3.61          | 3.11         | 4.00                     | -          |
| Number of productive branches (branches) 60 dpt | 4.78    | 4.56          | 4.00         | 5.06                     | -          |
| Flowering age (days)                    | 10      | 12            | 12           | 14                       | -          |

Note: Numbers followed by the same letters in the same column do not significantly different at the 5% probability level (LSD_{0.05} test)

3.2. Effect of pruning type on yield of old seedling of chili pepper

The results of the analysis of variance indicates that the pruning type has a very significant effect on number of fruit per plant, each fruit weight, weight of fruit per plant and plants productivity. Pruning types has a significant effect on the length of fruit, yet has no significant effect to the diameter of fruit. Average number of fruit per plant, fruit length, fruit diameter, each fruit weight, fruit weight per plant and plant productivity in several pruning types can be seen in Table 2.

More fruit is found in control and root pruning, which is significantly different from shoot pruning and the combination of shoot and root pruning. That is because photosynthates produced by plants without shoot pruning can trigger fruit propagation, thus photosynthates are not concentrated on branch growth. The results of [22] showed that in the treatment without shoot pruning, eggplant did not experience growth towards the side therefore photosynthates are used for optimal fruit formation.

The longest chili pepper is found in shoot pruning which is not significantly different from combination of shoot and roots pruning, but significantly different from root pruning and control. This might be due to the fact that shoot pruning can transport the photosynthates to the fruit so that the fruit is longer than without pruning. [23] stated that the results of photosynthesis from leaves and other photosynthetic cells must be transported to other organs or tissues, thus photosynthates can be used for plant growth.

The diameter of chili tends to be greatest in shoots and roots pruning, although statistically it does not show significant differences with other treatments. That is because the roots that have been cut will emerge a lot of branching roots so that the shape of the roots widen thus the plant canopy also widens. A wide header makes the process of photosynthesis more maximal and photosynthates are produced more. The photosynthate is then used for fertilization. This was explained by [16] that the treatment of
root pruning influences the development of seedling roots and the growth of the seedlings of the *G. gnemon* seedlings.

**Table 2.** Average number of fruit per plant, fruit length, fruit diameter, each fruit weight, weight of fruit per plant, and productivity in several pruning types on old seedling of chilli pepper.

| Parameters                        | Control  | Shoot pruning | Root pruning | Shoot and roots pruning | LSD$_{0.05}$ |
|-----------------------------------|----------|---------------|--------------|--------------------------|--------------|
| Number of fruit per plant (fruit) | 52.70 b  | 31.10 a       | 49.60 b      | 38.00 a                  | 9.54         |
| Fruit length (cm)                 | 11.50 a  | 12.50 b       | 11.50 a      | 11.90 ab                 | 0.63         |
| Fruit diameter (cm)               | 0.51     | 0.51          | 0.51         | 0.52                     | -            |
| Each fruit weight (g)             | 2.47 a   | 2.87 b        | 2.57 a       | 2.68 ab                  | 0.21         |
| Fruit weight per plant (g)        | 122.38 b | 86.05 a       | 119.34 b     | 93.02 a                  | 22.18        |
| Productivity (tons ha$^{-1}$)     | 4.10 b   | 2.9 0a        | 4.00 b       | 3.10 a                   | 0.74         |

Note: Numbers followed by the same letters in the same column do not significantly different at the 5% probability level (LSD$_{0.05}$ test)

The highest weight per fruit of chili pepper was found in shoot pruning which was not significantly different from the combination of shoot and root pruning, but significantly different from root pruning and control. This may be because the pruning of shoots can increase the number of branches and leaves that appear, therefore plant canopy is getting wider. The extent of the plant's canopy makes the process of photosynthesis progress more optimally and photosynthate is transplanted to the fruit (24). (25) stated that the treatment of shoot pruning in tomato plants can produce a higher weight per fruit than without pruning so that the resulting photosynthate is distributed for the formation of larger and heavier fruits.

The greater weight of chili pepper per plant was found in control and root pruning, which was significantly different from shoot pruning and the combination of shoot and root pruning. Fruit weight per plant is influenced by the number of chilies per plant. The amount of weight of chili per plant does not affect the weight per chili, this may be because the photosynthate produced is only used for fruit propagation, but not used for magnification of the size and weight of the fruit. (22) stated that eggplant plants with a large number of fruit will reduce the unit weight of the fruit, decrease in fruit unit weight due to the number of fruit caused by photosynthates produced are not enough to increase the size of the fruit, conversely the less fruit that exists the greater the size of the fruit and the fresh weight of the fruit.

The higher productivity of chili pepper is found in the control and root pruning, which is significantly different from shoot pruning and the combination of shoot and root pruning. The results showed that the productivity of plants classified as low, different from the potential yield of Perintis (the local chili pepper cultivar from Aceh) that can reach 7-8 tons ha$^{-1}$. This might be due to research using polybags, lack of fertilizer application, and growth conditions that are not appropriate, so that the potential yield of chili plants is not optimal. The growth requirements include altitude, planting media, rainfall, and sunlight intensity.

3.3. *Effect of pruning type on percentage of viral diseases*

Each type of pruning on chili pepper plants get a different percentage of viral diseases. Percentage of virus symptomatic plant at the age of 30, 45, 60, 75 and 90 dpt in several pruning types can be seen in Table 3.

Table 3 shows that from 72 observed chili pepper plants in the field at 30, 45, 60 and 75 dpt there were no viral symptomatic plants (0%). At 90 dpt, the control was having one of viral symptomatic plant (5.6%), and from whole pruning treated chili pepper plants (72 plants) there were two plants symptomatic (11.11%). The viral symptomatic plants are all included in the category of curly leaves.
but not yellowing (curling). This is because around the research area there were several cassava plants which are known as alternative host plants for whitefly (Bemisia tabaci), not to mention whitefly is the virus vectors for plants. Whitefly is very dangerous because they can be a viral vector that can eliminate 20-100% of plant yield. In addition, whitefly interruption on plant can also cause the curly leaves [26]. Pruning the shoots is able to cause easier viral infection. Viruses can penetrate through wounds or be inserted by intermediaries or vectors. Plant viruses are often carried and enter the plants through vectors such as fungi or insects. Symptoms of yellowing curly leaves are typical symptoms of Begomovirus. Viral infection in the early stages of seedling development will cause severe damage, and in such cases no fruit can be harvested [27]. But the viral infection occurred at the 90 dpt, thus plant was still able to produce well. The resistance of plants from viral infection may be due to the intensive level of plant care, such as spraying insecticides regularly to avoid whitefly.

Table 3. Percentage of viral diseases in several pruning types in old seedling chili pepper plants in growth and yield.

| Parameters          | Control | Shoot pruning | Root pruning | Shoot and roots pruning |
|---------------------|---------|---------------|--------------|-------------------------|
| Disease Incidence (%) 30 dpt | 0%      | 0%            | 0%           | 0%                      |
| Disease Incidence (%) 45 dpt | 0%      | 0%            | 0%           | 0%                      |
| Disease Incidence (%) 60 dpt | 0%      | 0%            | 0%           | 0%                      |
| Disease Incidence (%) 75 dpt | 0%      | 0%            | 0%           | 0%                      |
| Disease Incidence (%) 90 dpt | 5.56%   | 11,11%        | 11,11%       | 11,11%                  |

In root pruning, the disease that commonly infect is falling over sprout which caused by Pythium sp. The disease caused by Phytophthora sp. always started from the root tip (main root or lateral root). This disease only occurs if the planting soil is contaminated with pathogens or unsterile [15]. But in this study, there were no symptoms of plants affected by Pythium sp.

4. Conclusion
Pruning type has a very significant effect on the growth and yield of old seedling of chili pepper plants, such as plant height, stem diameter, number of fruit per plant, each fruit weight, fruit weight per plant, and crop productivity, has a significant effect on the fruit length, yet has no significant effect to the number of productive branches and diameter of the fruit. Plant height, stem diameter, number of fruits per plant, fruit weight per plant and highest crop productivity are found in root pruned and control. The high fruit length and each fruit weight can be found at the shoot pruned plants and the combination of shoot and root pruned. The highest number of productive branches of the plant and the diameter of the fruit are found in the combination of shoot and root pruned chili pepper plants. The fastest flowering age and the lowest percentage of viral symptomatic plant is the control.

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