Improving the production and quality of virginia tobacco through topping and suckering: A Review

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Abstract. Tobacco production in Indonesia continues to increase along with the number of requests tobacco industry due to the shift in consumer tastes from smoking kretek cigarettes to white. Virginia's domestic tobacco has not been able to cover the needs of the tobacco industry, so part of this is fulfilled from imported tobacco. In terms of cultivation, the emergence of flowers resulted in stunted growth and decreased quality of tobacco. Increasing tobacco production and quality can be done by applying Good Agriculture Practices (GAP) by cutting the top (topping) and removing side shoots (suckering). The timely application of topping and suckering can increase the production of tobacco leaf accompanied by an increase in the quality of the tobacco leaves produced. Based on the research results, it is known that topping and suckering treatment can increase production by 60-80% and nicotine levels by 40-60%. The application of suckercide can reduce labour costs without reducing the yield, quality, and chemical content of tobacco. The impact of increasing production and quality of Virginia tobacco will increase farmers' bargaining power and economy.

Keywords: cultivation, increasing, tobacco, leaves.

1. Introduction
The production of virginia tobacco in Indonesia continues to increase from year to year. In the three centers of virginia tobacco production (viz. East Java, Bali, and West Nusa Tenggara), the production increase from 39.189 tonnes in 2016 to 47.936 tonnes in 2017 [1]. In addition, it is well known that tobacco is one of the crucial commodities due to employs a large number of people or labour-intensive. Based on data from the Ministry of Industry, the tobacco cultivation process until the tobacco product industry engages at least 5.9 million employees. The 5.9 million employees were consisting of 4.2 million in the manufacturing and distributing process and 1.7 million in the plantation [2].

Increasing demand for virginia tobacco caused by shifts in cigarette costumer tastes from kretek to mild (white) cigarettes. It was proved by an increase of 46.67% of tobacco virginia import from 81.502 in 2016 to 119.545 tonnes in 2017 [3]. Increasing in imports could be controlled and reduced by increasing the production of domestic virginia tobacco.

Several methods could be applied to increase tobacco production. Some of them are topping and suckering as a part of Good Agricultural Practices (GAP) in tobacco cultivation. Topping and suckering are related to the flowering process in the tobacco plant. The flowers on the tobacco plants reduce growth and harvesting yield, which affects economic outcomes. The purpose of topping and suckering is to improve the physical appearance and quality of tobacco yield. Tobacco plants will have more width and thick leaves, improve in mass, yield, and quality.
2. Material and methods
This research is a descriptive research, conducted in a tobacco plantation area that applies topping treatment and untreated. Then compare plant growth and production and quality produced. The research was conducted in March-May 2016 in several areas in East Java such as Probolinggo, Situbondo, Bojonegoro and Madura.

The results obtained are then compared with several research results from several literature studies, especially regarding the chemical characteristics of the treated plants.

3. Result and Discussion
3.1. Flowering on tobacco plant
Tobacco plants are indeterminate plant with the end of the growth phase when they begin flowering. The swiftness of flowering is affected by auxin activity as a dominant substance in shoots. When the auxin activity is low, flowering will happen faster. The low activity of auxin is a consequence of the activity of cytokinin and GA3 in plant tissue. Several researchers reported the trigger of flowering caused by increasing cytokinin content in the plants. On the other side, promptness of flowering is affected by GA3 application [4]. Generally, flowering in tobacco plants occurred 60-70 days after planting. However, not all plants have the same condition, depending on genetic and treatment included variety and type of tobacco plant, temperature, transplanting process, and watering.

According to research result by [5], there is some difference in phenology between virginia tobacco varieties. The result shows that each variety has different flowering age, pruning age, and final harvest age when grown in the same agroecology. It shows that the plant phenology of tobacco was influenced by plant genetic. Opine of [6] that flowering on tobacco plants is a fully autonomous pathway that forms several nodes before flowering, regardless of its growing environment. Nevertheless, changes in a single gene could be switch to tobacco plants that require short days to flowering [7]. Meanwhile, flowering stimulation of tobacco plants at low temperatures (15°C) is more marked with increasing age, while flowering is delaying at high temperatures [8].

Flowering stimulation on tobacco plants due to low temperature has more effect in a seedling that is too old in the nursery. On the other hand, flowering induction is also due to faster seedling transplantation [9]. Induction of flowering has started on the seedling. Nevertheless, the induction risk of flowering will reduce when the seedling experiences dryness before transplanting. Besides that, flooding also causes the flowering of tobacco faster. Result of research shows that earlier seed transplantation can improve flower bud differentiation and induces early bloom. The condition can reduce leaves number and the harvest yield of tobacco, especially if the seed is in poor condition, low-temperature condition, and lack of sunlight during the early growth period [10].

The presence of flowers on tobacco plants is required when intended to produce tobacco seeds. Nevertheless, flowering becomes unfavourable due to caused thinner and tighter leaves that can reduce the leaves production and the quality. It is because the primary purpose of tobacco farmers is to produce high yields and high-quality tobacco leaves.

3.2. Topping and suckering definition
One of the efforts to overcome flowering problems, which can improve the production and quality of tobacco, is topping and suckering [11]. Topping or trimming the top of plants aims to remove the flower. Removing flowers will obstruct seed formation and accelerate leaf ripening (on the vegetative stage) [12]. Moreover, topping has a significant effect on growth and plant development, including hormone, root development, nicotine synthesis, and stress tolerance [12]. Topping activity, ideally done when a flower is still a form of button stage or when the top leaves have rolled up. It aims to reduce apical domination to distribute the nutrition to the leaves. Besides topping, another important activity is suckering. Suckering aims to remove the side shoots (sucker), which generally grow after topping. Topping initiated to side shoot growth due to the leaves on the axilla activated from the dormant stage after topping,
Side shoots, which grow on the top of a plant and the leaf axilla, will grow better and faster than the primary stem because the side shoot is more competent to get essential plant nutrition. Besides the competition on nutrition and sunlight, side shoots increase the environment humidity around them, affect planting distance, and suitable environment for plant pests and diseases. Tobacco plants produce three side shoots on every leaf axilla caused four to five times to suckering for a lifetime of plants [13],[14]. Manual suckering can be discontinued four to five days before harvesting [15].

Suckering can be done manually or use a chemical plant growth regulator called suckercide. Several research show that controlling the sucker by suckercide was more effective than manually and can increasing the leaves production [13],[16] and improve farmer income [17]. Suckercides have been widely abroad with various types of active substances. According to [18], three types of suckrecide are commonly used i.e. :

3.2.1 Contact
The active substance for its type is long-chain fatty alcohol that can damage the plasma membrane. The condition caused dehydration and side shoot demised.

3.2.2. Systemics
Systemics type controls the side shoots by infiltrating to the leaves and translocated to the leaves axilla. At the leaves axilla, the substances obstruct cell division and side shoot formation. Nevertheless, some researchers consider the systemic suckercide potentially carcinogenic. An example of systemic suckercide is maleic hydrazide.

3.2.3. Locally contact-systemics
This suckercide is absorbed when attached to the plant tissue and further obstructs the side shoot growth by inhibiting cell division. This type has the active substances dinitroanilin, for example, are flumetraline and pendimethalin. Topping and application of locally contact-systemics suckercide affect the gene expressions in the auxin and cytokinin pathways. The pathways are bound to side shoots formation. According to [13] dan [16], pendimethalin application can reduce side shoots. Its impact significantly improves the harvest yield of tobacco leaves than manually suckering.

3.3. The benefits of topping and suckering
Some benefits of topping and suckering on tobacco plants are
- Maximize tobacco to produce leaves and promote leaf ripening [12,19]. Topping caused improving the size and mass of leaves. It caused increasing tobacco leaves production per hectare [20, 21, 22, 23]. The change of leaf characteristics after removing the flower and suckers was not caused by new cell formation but by an increase in the size of cells. Nevertheless, not all the leaves have the same effect. Younger leaves have a high impact because of topping. Old leaves in the lower steam have a negligible impact of topping.
- Switch from the generative to the vegetative phase of plants [12, 19]. Without flowers, the plant nutrition is distributed to the leaves, not to flowers and seeds. Therefore the leaves got thicker and wider. The plants produce uniform leaf quality and avoid the formation of leaves that are too diverse.
- Improve root growth [24]. Good roots development can improve the potential of water dan nutrition absorption, increase the endurance of shoot from wind, and increase the nicotine synthesis. On the other hand, it can increase the yield by escalating the plant growth especially top leaves and stimulate the plant to produce secondary metabolites in the leaf [25].
- Decrease the weight of top plant [24]
- Decrease nutrition translocation and leaf humidity to support growth and develop the top leaves [24]
- Increase nicotine and reduced sugar content in the leaves
Topping is a crucial point for nicotine synthesis that caused nicotine accumulation in the plants [26]. Before topping, the nicotine content is relatively low because approximately 2.5% nitrogen can be absorbed and used for nicotine synthesis. Meanwhile, the proportion of nitrogen absorbed for nicotine synthesis reached >16% after topping. It caused a significant increase in the nicotine level of tobacco plants [27]. According to [28], topping and suckering improve nicotine level by 59% and reduced sugar by 37% (Table 1).

3.4. Influencing factors of topping and suckering

3.4.1 Order of execution. Topping and suckering is the significant thing to reach the objective of tobacco cultivation specifically, to increase the yield and quality of tobacco leaves. Nevertheless, topping without suckering give a different effect to the harvest yield, as shown in Table 1. While the research results of [29] stated that topping and suckering could increase yield, alkaloids (nicotine content), and sugar content more significantly when compared to just topping treatment alone as shown at Table 2.

Table 1. The effect of topping and suckering to the yield, alkaloid (nicotine), and reduced sugar on tobacco leaves[28].

| Treatment                  | Yield (kg/ha) | Alkaloid (nicotine) (%) | Reduced sugar (%) |
|----------------------------|---------------|-------------------------|-------------------|
| Without topping and suckering | 1,390         | 1.76                    | 13.30             |
| Topping without suckering  | 1,487         | 2.36                    | 17.30             |
| Topping and suckering      | 1,806         | 2.80                    | 18.20             |

Table 2. The effect of topping and suckering to the yield, alkaloids (nicotine content), and sugar content on tobacco leaves[29].

| Treatment                                      | Yield (kg/ha) | Alkaloid (nicotine) (%) | Sugar content (%) |
|------------------------------------------------|---------------|-------------------------|-------------------|
| Control (Without topping and suckering/spraying)| 3,313         | 1.71                    | 8.83              |
| Control (Topping without suckering/spraying)   | 3,340         | 2.06                    | 9.19              |
| Full treatment (Topping and suckering/spraying)| 4,639         | 2.30                    | 10.38             |

3.4.2 Time. The success of topping and suckering is also affected by the time when the activity occurred. Late topping and suckering caused some adverse effects. The most incredible adverse effects are yield and quality reduction of tobacco leaves. A research study shows that a yield reduction of 12.25% has occurred when topping done at the end of the flowering period than at the early period [28], as shown in Table 3. Another research result about the effect of topping time suggest the same thing as shown in Table 4.

Table 3. The effect of topping time to the yield, alkaloid (nicotine), and reduced sugar of tobacco leaves [28].

| Time of topping            | Yield (kg/ha) | Alkaloid (nicotine) (%) | Reduced sugar (%) |
|----------------------------|---------------|-------------------------|-------------------|
| Mose/early flowering *)    | 1,910         | 2.59                    | 21.8              |
| Early flower bloom         | 1,890         | 2.02                    | 22.8              |
| Full of flower bloom       | 1,774         | 1.86                    | 21.8              |
| End of flowering           | 1,676         | 1.95                    | 20.0              |

*) Seven days different between flowering phases
Table 4. The effect of topping time to the yield and nicotine content of tobacco leaves [30, 31].

| Time of topping               | Yield (kg/ha) | Alkaloid (nicotine) (%) |
|-------------------------------|---------------|------------------------|
| Mosel/early flowering         | 3,850         | 4.30                   |
| Early flower bloom            | 3,406         | 3.80                   |
| Full of flower bloom          | 3,384         | 3.20                   |

Moreover, according to [30], topping and suckering on time can increase the yield of tobacco leaves in the form of fresh or dry. It is also supported by an increasing the number of harvested leaves from each treatment. Topping at the early flowering can produce good physical characters namely good texture and elastic leaf. The best treatment of topping was in at button stage of flower and removal of 22 leaves of tobacco with increase of fresh leaf yield about 19.4% and dry leaf yield about 34.3% compare to the plants with no treatment. Consequently, it improves the income of the farmer. Some research also reported that topping on time generates suitable physical and chemical characters and resulting high yield and best quality product [20, 32, 33]. Based on [29] research, earlier topping produces higher leaves nicotine content compared to the plants with topping treatment at the early flowering and full flowering, and also without no treatment.

Time of topping is also an important key that affects leaf quality. Late topping caused increasing the number of suckers that have to be removed. The height of topping is related to ease of labour to doing topping and suckering. Over-height plants complicate the harvesting process, are laborious, difficult for the following process and post-harvesting. Moreover, the yield of tobacco leaves will not increase when the plant is topped removing beyond 22 leaves removed. In addition, increasing the height of topped plants can reduce the total alkaloid content, increase the yield, and do not affect the reducing sugar content [21].

3.5 Tobacco leaf characteristic after topping and suckering
Tobacco plants undergo a series of physiological and biochemical metabolic processes during the growth and development phases. Dynamic and temporal changes of tobacco leaf metabolite have a significant effect on leaf substrates related to the quality and flavour [34]. In addition, the chemical composition of tobacco leaves is very dependent on the environment, genetics, and spatial position. Multivariate tobacco leaf analysis shows a significant difference in metabolic profile between the bottom, middle, and top leaf during the ripening process. During the growth phase, changes of tobacco metabolite are more remarkable on the stalk [35], some of the metabolites extracted from tobacco leaf as shown in Table 5.

Table 5. Metabolites extracted from tobacco leaf identified by GC/MS [35].

| Amino acid                        | Sugar compound and their derivates | Organic acid and fatty acid | Others                                      |
|-----------------------------------|-----------------------------------|-----------------------------|---------------------------------------------|
| L-Alanine 1,2                     | D-threitol                        | Butanoic acid               | N,N-dimethyl-ethanolamine                    |
| L-Valine 1,2                      | 2-Deoxy-D-ribose                 | Pyruvic acid                | 2,2,4,6,6-pentamethyl-heptane               |
| Glycine 1,2                       | D-Xylose 1,2                      | L- (+) Lactic acid          | 2-hydroxypyridine                           |
| L-Leucine                         | D-Arabinose                       | Glycolic acid               | Phosphate                                   |
| L-Proline 1,2                     | Xylitol 1,2                       | 2-hydroxyl acrylic          | Nicotine                                    |
| L-Serine                          | L-Rhamnose                        | 2-Pyrrolidone five carboxylic acid | 2(3H)-Furmanone, dihydro-3,4-bis[(trimethylsilyl)oxy]-,trans- |
| L-Threonine                       | Ribitol                           |                             | Nornicotine                                 |
| L-Aspartic Acid                   | Phospho-glycerol                  | Benzoic acid                | Myosmine                                    |
| 5-oxo-L-Proline                   | D-Fructose 1,2                    | Propanedioic acid           | Anatabine                                   |
| L-Phenylalanine                   | D-Mannose                         | Maleic acid                 | Cotinine                                    |
| 1,2                               | D-Galactose                       | Succinic acid               | Putrescine                                  |
| L-Glutamine 1,2                   | D-Glucose 1,2                     | Glyceric acid               |                                            |
Based on [36] research, manual and chemical suckering generate a different effect. Manual topping raises nicotine content due to the wounding induces changes of auxin flux. Escalation of auxin content leads to increased nicotine content as a defence system. It does not occur on chemical topping using suckericide.

The topping on tobacco plants prevents the generative phase (seed forming) and generates sucker development. Therefore, topping and suckering correlate with each other [37]. Suckercide application is considered effective in preventing the formation of suckers. Maleic hydrazide in suckercide will be absorbed and distributed in the plant to inhibit cell division in meristematic tissue. It is causing growth as a result of the expansion or elongation of existing cells. Hence the leaves get bigger and broader. However, this doesn’t apply to leaves with a size of <20 cm and shoots because the shoots will be shorter and narrower [38][39]. In addition, [23] reported that the application of suckercide at early flowering improves the size and quality of tobacco leaves. Furthermore, suckercide application is an alternative to reduce the cost of the labour force on manual suckering without decrease the yield, quality, and chemical compound of tobacco leaves [40].

4. Conclusion
The application of good agricultural practices by topping up and suckering in a timely manner can produce domestic production that has high competitiveness accompanied by increased production and quality, thereby reducing tobacco imports. Based on several research results, it can be seen that the topping and suckering treatment can increase production by 60-80% and nicotine content by 40-60%. The application of suckercide can reduce labour costs without reducing the yield, quality, and chemical content of tobacco. The achievement of good production and quality will increase high bargaining power and farmer income.

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