The application of several cultivation practices on growth and production of chili (Capsicum annuum L.) varieties in the rainy season

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Abstract. Application of chemical pesticides may cause significant negative impact on production and quality of Chili. Therefore, implementation of friendly environmentally based cultivation practiced is absolutely needed. The purpose of this research was to evaluate the growth and the yield of chili (Capsicum annuum L.) varieties grown by using three cultivation practices. This study was conducted in Bengkayang region, West Kalimantan Province, Indonesia, from August 2019 to February 2020. A Nested Factorial Randomized Block Design with three replications was arranged. The subplots were the commercial chili varieties (Lingga, Kencana, and Leket as a local one) and main plot were cultural practices, i.e., CO: friendly environmental-based technology (i.e., increased plant population from 20,000 to 30,000 plants/ha, the using of biopesticides, trapping, and maize as barrier plant; CP: recommended technology (CO + a recommended pesticides), and CF: farmer technology-based. The results showed that the plant height of Leket on CO treatment was the best until eight weeks after planting; whereas the widest plant canopy was found in the Lingga. More than 30% of plants were attacked by pests and diseases that cause curling leaves. The Leket was the most sensitive to curl (40%); on the other hand, CO treatment decreased this symptom by 5.5%. In terms of yield, the Kencana produced the highest fruit number per plant (142), and the CP treatment had the most harvest frequency. Percentage of ripe fruit weight loss after one week of storage was about 12-22% with the most severe was Lingga. In this area during the rainy season, the highest potential yield was on the CO treatment (17.5 tons/ha). These results indicated that environmentally friendly cultivation on chili could be developed in this season.

1. Introduction
West Kalimantan Province shares land borders with Sarawak - Malaysia, close to the Entikong border gate, which makes this area is proclaimed to be one of the national food storage areas on the border, with the main centers being Sanggau, Sintang Sambas, Kapuas Hulu and Bengkayang Regencies. With
this strategic position, it will make it easier for the region to export agricultural products. Horticultural products that offer the opportunity to be exported to Sarawak include red and small chili.

The harvested area for large and small chilies originating from 17 Subdistricts in Bengkayang Regency in 2019 reached 289 hectares with a total production of 1,406.3 tons [1]. With 255 thousand residents, and an average per capita consumption of 1.6 kg/capita a year, the demand for chili for public consumption is estimated at 408 tons per year. The excess production is likely to be exported to border areas and other regencies in West Kalimantan Province.

Apart from having the potential to be exported, nationally, chili is also a source of inflation in Indonesia at certain times. For example, during celebrations of special holidays, in the rainy season, and others. According to Statistics Indonesia in June 2019, Indonesia experienced inflation of 0.55% and one of the factors was caused by the price of red chili which contributed to inflation by 0.2% [2].

Numerous efforts were made by the Government to suppress this inflation, among others, by encouraging increased production, quality, and competitiveness so that prices and levels of availability were relatively stable over time.

For the success of the Food Security Strengthening Program, through the Indonesian Agency for Agricultural Research and Development (IAARD), “Proliga” (multiple production) is carried out to chili to increase production by farmers. As reported [3] that the level of efficiency of chili production by farmers based on the DEA model was 0.940, which means that farmers must reduce input by 6% to be more efficient. Production improvement with Proliga technology is carried out by assembling its cultivation components, namely the use of superior varieties, healthy nurseries, increasing plant population density from 20,000 to 30,000 plants/ha, managing soil, nutrients and water, as well as rational control of plant pests, among others by reducing chemical based inputs. With its implementation, the productivity of red chili is expected to increase from 8-10 tons to 20 tons/ha [4]. This technology is equally purposeful. Until now, the application of Proliga technology for on-season chili has been mostly carried out in Java, while off-season studies have been developed in locations that have different climate typologies from Java, such as the NTB, NTT, North Sulawesi and Southeast Sulawesi regions [5]. Of the various demonstration plots carried out, this technology package was able to generate productivity of 15.81 tons/ha - 22.78 tons/ha, with profits earned from Rp120,696,305 to Rp286,076,305 or Rp15,087,038 per month to Rp35,759,538 per month [6].

The success of Proliga technology in increasing chili production is strongly affected by environmental factors such as light, water and temperature. According to [7] high temperature conditions in the vegetative development phase of chili will affect fruit growth, yield and quality of chili seeds due to inhibition of the carbohydrate accumulation process. The smaller the number of seeds per fruit will reduce the size of the fruit. Apart from temperature, water shortage and excess as well as differences in planting time will also affect production [8,9]. In the generative phase, red chili can only withstand a maximum of three days of inundation, more than that will increase the risk of death[10]. Adequacy of light also affects growth and production, where up to 50% shading will reduce the potential yield to 84.4% [11].

Varieties components in Proliga technology have a big influence on production. In general, each variety will have a different response to environmental factors [12]. In Indonesia, one of the most widely grown curly chili is the Kencana variety. This variety comes from the selection results of the Indonesian Vegetable Research Institute (IVEGRI), including the self-pollinating group with plant height of 112.6 - 125.6cm. Flowering and fruting ages are 34-39 and 95-98 days, respectively after planting. The characteristics of this fruit are red, spicy with a capsaicin level of 355.8 ppm, relatively thin skin, namely 0.45 - 1.00mm, fruit length is 11.0 - 12.8cm and weight per fruit is 4.4 - 6.4g. The advantage of this variety is high production, that is, the number of fruits per plant can reach 289 fruits with a production of 0.55 - 0.87kg (12.1 - 22.9 tons/ha). In addition, this variety is well adapted to the medium plains at an altitude of 510 - 550m above sea level in the wet dry season [13]. Apart from Kencana, another superior variety selected by IVEGRI is Lingga. This variety is a red chili that has a high production potential. The fruit skin is thicker, namely 1 - 2mm, fruiting earlier than Kencana, which is 88 - 95 days after planting. Fruit length is 11.2 - 12.9cm, with weight per fruit is 9.5 - 11.0g; the amount per plant
reaches is 75 - 114 fruit or 0.591 - 0.878kg (13.4 - 20.5 tons per hectare) [14]. Meanwhile, the local variety that is often found in the border areas of West Kalimantan is Leket, which comes from Sarawak, Malaysia and is very popular with the people of Bengkayang. In general, this chili has the advantage of being large in size, fruit length is 11-17cm with a weight of 18-28g per fruit, and a thickness of the fruit skin is ≥ 1.5mm.

Applying the Proliga technology in horticultural production centers of Bengkayang Regency, it is hoped that the chili production can be relied on to meet the needs of the surrounding community and can act as an export commodity in accordance with the program that has been launched. The purpose of this research was to evaluate the growth and the yield of three varieties of chili (*Capsicum annuum L.*) grown by using three cultivation practices.

2. Materials and Methods

2.1. Description of the Research Area

The research was conducted at Kampung Baru, Bange Village, Sub-District Sanggau Ledo, District of Bengkayang, West Kalimantan Province from August 2019 to February 2020. Bange is at ± 159 m above sea level, with latitude of 1°5′43′′S dan longitude of 109°41′55′′ E. The weather data (Figure 1) during the period of research (January 2019 to January 2020) revealed that the annual and average rainfall/month are 3.636 mm and 303 mm/month, respectively; where the seasonal distribution of rainfall during the research (August 2019 to January 2020) was 1.852 mm with the average was 308.7 mm/month.

![Figure 1](image-url)  
*Figure 1. Monthly rainy days and rainfall during January 2019 to January 2020 (Subdistrict Sanggau Ledo).*

2.2. Experimental Design

This research used a factorial plot nested design. The main factor was three varieties of red chili and the sub-factors were three cultivation methods. The method of cultivations was: 1. Proliga using biopesticide (CO) treatment, 2. Proliga + minimal pesticide treatment recommended by IVEGRI (CP), and 3. Farmer technology (CF). The varieties used were Kencana, Lingga, and Leket (existing variety), with 3 replications. Each treatment unit consisted of six plots, each with a size of 1 x 9 m. In the CO and CP treatment, each bed contained 32 plant holes, 1 and 2 plants were planted per plant hole in a zig zag manner so that the number of plants was 48. In the CF treatment, each bed contained two rows, each row contained 16 plants so that the number of plants was 32.

2.3. Seedling Preparation

Chili seed nurseries for CO and CP treatment were carried out in a screen house. The nursery was done singularly in a container made of banana leaves with the planting medium consisting of a mixture of fine soil and manure (1 + 1) plus Bio-tricho. Prior to the nursery, the location was sterilized by spraying the
insecticide, Tiamethoxan (1.0 ml/l) and installing a yellow trap to monitor *Bemisia tabaci* until the population was zero. When the seedlings were three weeks old (three true leaves), pinching was done to multiply the branches. A week before transplanting, seedlings were sprayed with Pagoda leaf indoozer (*Clerodendrum japonicum* Sweet) to stimulate increased resistance of chili plants to yellow curl virus disease. Whereas in the farmer method (CF), the nursery was in open land protected by simple shading.

2.4. *Border plant*

Planting maize as border plants in each of the CO and CP treatments was carried out before planting chilies, with a distance of 1 m around the land. Maize plot width was 1.5m. The planting was carried out in two stages, each as many as 3 rows in one month before and after planting chilies, with a distance between rows of 25cm and a distance between plants in one row was 20cm, and two maize seeds per planting hole.

2.5. *Land Preparation*

The land was ploughed 2-3 times and brought to a fine tilth. The land that has been cleared was loosened and made for beds 1 m wide with a height of 25-30cm. The distance between the beds was 60cm. The basic fertilizer consisted of NPK 16-16-16 (500 kg/ha) and ZA (200 kg/ha) fertilizers, which were sown on the kerf. In the CO and CP treatment, bokashi compost was added with a mixture of goat and chicken manure (20t/ha). All mounds were covered with plastic mulch. Mulch perforation was carried out five days before planting, with the location of the holes according to the spacing between and in the rows was 70 and 50cm, respectively.

2.6. *Planting and cultivation*

Transplanted seedlings were healthy plants. When it grew, the plant was staked so that it grew upright. Replanting was done when there were dead plants. Cultivation was carried out on a standard basis to control the pest. In the CO treatment, spraying was done by using the biopesticide i.e tuba root mixed with lemongrass and galangal, meanwhile in CP, apart from being biopesticide, pest control was also carried out with chemical one if necessary. In the treatment of farmers, control was performed by the type and dose of pesticides according to their habits. Provision of follow-up NPK 16-16-16 fertilizer was done at a dose of 2 g/l, which was splashed into the plant hole or around the plant.

2.7. *Data Collection*

Plant height was measured in centimeters from the soil surface to the tip of matured leaf in the plant using a ruler. Leaf numbers were obtained by counting their total numbers per plant. Initial observations of fruiting and symptoms of curling were carried out at week 10 after planting; the next harvest was carried out every week thereafter until the end of February 2020. These data were collected every week starting from 2 to 22 weeks after planting. Ten plants per replicate were considered data.

Harvest data observed were the number of fruits/plot, harvest frequency, fruit weight/plot, fruit/plant weight, and yield potential per hectare. In addition, observations were also made on the percentage of fruit loss during storage. The chilies used as samples were those that have been physiologically ripe but were still green and those that have been red. The sample was placed in the open for one week. The percentage of fruit weight loss during storage was calculated by the formula: % shrinkage of fruit = (fresh weight-weight after storage)/fresh weight*100%

3. Results and Discussion

3.1. *Plant Height and Size of Canopy*

Plant height at the age of 2 and 4 weeks after planting (WAP) was not significantly affected by the interaction between varieties and their cultivation. At that age of 6 weeks, variety and planting cultivation treatments had a significant effect on plant height separately (Figure 2). In general, the local variety of Leket had better growth than Lingga and Kencana, while the biopesticide treatment (CO) had
an optimal growth effect compared to CP and CF technologies. According to Islam et al. [15], the increase in population caused by dense spacing had a significant effect on almost all components of growth and production. It was assumed that in this condition, plants got less than optimal light, nutrients and other essential elements. Lack of light intensity caused by shade will affect plant growth [11].

The height of the chili plants at the age of 6 WAP showed an interaction between varieties and cultivation. The highest chili plant was Leket variety with CO cultivation reaching 73.90cm, while the lowest was Kencana variety which was managed by CF which reached 46.17cm. At the age of 8 WAP, plant growth showed the same pattern as the previous age. This vegetative growth is strongly affected genetically and how to cultivate it. The addition of organic matter to the media greatly affects the growth and production of chilies due to an increase in soil fertility with increased levels of C-organic, N-binding bacteria and phosphate solubilizing bacteria [16, 17].

**Figure 2.** The average plant height of three red chili varieties (a) and three ways of cultivation (2 - 8 WAP). CO: Biopesticide Cultivation; CP: Proliga Cultivation; CF: Farmer Cultivation method

The growth of the plant canopy at the age of 2-8 WAP was only affected by differences in varieties (Figure 3). This was thought to be due to the genetic characteristics of the plant, where at the age of 8 WAP, the Lingga variety had a wider canopy of 13.2 and 15.1%, respectively, than Leket and Kencana varieties.

**Figure 3.** The average canopy width of three red chili varieties (2 - 8 WAP)

### 3.2. Percentage of plants that enter flowering phase and bear fruit at early yield

At the age of 10 WAP, the Lingga and Leket varieties have begun to bear fruit and in harvest phase, while the Kencana variety has just entered the flowering phase and began to bear fruit. According to the description of the existing varieties [13, 14], Lingga and Kencana will flower respectively at the age of 35-41 and 34-49 days and harvest at the age of 88-95 days and 95-98 days respectively after planting.
From this research, at the age of 10 WAP, the percentage of plants in the generative phase was not affected by the treatment of the variety, cultivation method or interaction. The average percentage of plants flowering and fruiting simultaneously ranged from 77 - 89%. Lingga variety and the method of CO cultivate had a relatively lower percentage of plants in the generative phase than the others (Figure 4).

3.3. Percentage of Plants Affected by Curly Disease with an Intensity of > 30%

At the age of 10 WAP, with high humidity conditions, the plants were attacked by thrips leaving scars with symptoms of curling on the leaves of plants. In addition, some plant curls were also caused by a yellow virus. The interaction treatment between varieties and cultivation methods did not significantly affect the percentage of plants with curly symptoms with an intensity of > 30%. The symptoms of this attack were significantly affected by the variety and its cultivation method. Leket variety was more sensitive to attack than the other 2 varieties, as well as the treatment of farmers’ cultivation (Figure 5). The higher percentage of plants attacked by curl disease in farmers’ cultivation may be due to the absence of Pagoda flower inducer spraying treatment and barrier maize plants so that the planting area was more open.

The Pagoda flower inducer sprayed on the CO and CP nurseries acted as an induction of the systemic resistance of red chili plants against the Cucumber Mosaic Virus (CMV) [18]. In the field, this extract also functions well on cayenne pepper and long bean plants [19, 20]. In addition, the presence of barrier maize plants is quite effective in increasing the population of Menochilus sexmaculatus which is a
predator of *Bemisia tabaci*, thus reducing the spread of yellow virus and increasing production in chili plants [21, 22].

In long bean plants, the application of maize planting as a barrier combined with Pagoda flower leaf extract was able to reduce the attack of the Bean Common Mosaic Virus (BCMV) by 68.43% [20]. In addition to inducer, spraying of tuba root extracts carried out on CO and CP treatments can reduce the *Trips pavispinus* pest [23]; while the biochemical content in the lemongrass plant can control *Helicoverpa* fruit borer [24]. The incidence of plants whose growth is not optimal, can also be caused by rainfall and high environmental temperatures [25].

### 3.4. Total number of fruits/plant per plant

The average number of fruits/plant was not affected by the interaction between varieties and their cultivation method. The number of fruits per plant was significantly affected only by differences in varieties ($R^2 = 87.05\%$) (Figure 6a). Leket variety had the lowest number of fruit compared to other varieties. The small number of fruits in the Leket variety was thought to be due to the size of the fruit which was significantly larger than that of Lingga and Kencana varieties ($R^2 = 85.93\%$), so that the ability of plants to form fruit was more limited (Figure 6b). The larger the fruit size of a variety, the smaller the total fruit per plant, where $Y \text{ (Total fruit/plant)} = 125 - 4.42 \times (\text{fruit size})$.

**Figure 6.** The average of number fruits/plant (a) and fruit size (g) (b) on three chili varieties.

Based on production standards (IVEGRI), the Lingga variety adapts well to medium plains with an altitude of 510 - 550m above sea level in the wet dry season, with the number of fruit/plant ranging from 75 - 114. Meanwhile, in Kencana variety, the number of fruits can reach 141 - 289. From this activity, it was found that during the rainy season, the Kencana variety was only able to produce at the minimum limit of its capacity.

### 3.5. Harvest Frequency

The first harvest of fruit can be done at week 10 for Lingga and Leket varieties, while Kencana one was at week 13. This is in accordance with its genetic characteristics, where Kencana can be harvested at an older age than Lingga. The harvest frequency was significantly affected by the variety and cultivation method, where the Kencana variety and CP treatment had a higher harvest frequency than others. On the other hand, the interaction treatment had no effect. Up to 159 days after planting, the total harvest can be done 12 times. Separately, the most harvestable variety was Kencana and the CP treatment with 7 and 7.5 harvest times, respectively (Figure 7).

In accordance with its genetic characteristics, Kencana has a good ability to adapt and production. The good harvest in the CP treatment is thought to be due to the addition of bokashi compost. According to [26], the application of organic fertilizers will promote growth, significantly increase pepper’s early yield, total yield, total number of fruits per plot, and fruit length and diameter. In addition, the frequency of harvesting on this plant is strongly affected by the ability of the plant to bear fruit; the higher the
ability of the plant to bear fruit, the higher the harvest frequency, where \( Y \) (harvest frequency) = 5.05 + 0.0158 total fruit/plant.

![Figure 7](image-url) **Figure 7.** The average of harvesting frequency on three chili varieties (a) and three cultivation methods (b)

3.6. *Potential Production per Hectare*

Plant production potential per hectare was only affected by the cultivation treatment. The production of the CO treatment was 161.2\% higher than the CF one. Meanwhile, in the variety one, although there was not significantly different, production of Leket was relatively higher than others. This was thought to be due to the fact that Leket is a local variety that has already adapted better than others. At this location, the production capability of Kencana and Lingga only reached 9.95 and 13.05 tons, or about 82.2\% and 97.4\% of their minimum potential capacity, respectively [13, 14]; while Leket can reach 14.86 tons (Table 1).

| Treatments         | Production/ha* |
|--------------------|----------------|
| Variety            |                |
| Kencana            | 9.95           |
| Leket              | 14.86          |
| Lingga             | 13.05          |
| Cultivations       | ns**           |
| CP                 | 13.63 ab***    |
| CO                 | 17.56 a        |
| CF                 | 6.70 b         |

\( R^2 (\%) \) = 55.17

* hectare with 70\% of beds and 30\% ditches

** ns = not significantly different according to DMRT at 0.05 level; CO: Biopesticide Cultivation; CP: Proliga Cultivation; CF: Farmer Cultivation method

*** In the column with the same letter are not significantly different according to DMRT at 0.05 level

Chili fruit that is in demand by consumers is generally based on its performance and taste; excellent performance (no defects, ideal size), or not rotting. From the selection results, it was found that the production of fruit with A grade category (which was sold in the market) per plot was not affected by the interaction of the treatment of varieties by cultivation; but separately affected by each variety treatment and cultivation. Lingga variety and CO cultivation methods produced the best grade fruit (Grade A) (Table 2).

The high percentage of rejected fruit is generally caused by defects due to disease. In the rainy season, many rot fruits occur due to anthracnose caused by the attack of the fungus *Colletotrichum capsici*. This fungus thrives in humid and wet environments. In CO treatment, the addition of organic fertilizers is thought to have improved the physical and chemical properties of the soil, namely an increase in C-
organic and CEC of soil. This will support the development and activity of plant roots in absorbing nutrients needed for plant growth and development [27].

Table 2. The A grade of fruit production/plot of three red chili varieties with three ways of cultivation

| Treatments   | A Grade/plot (kg) | % rejected fruit |
|--------------|-------------------|------------------|
| Variety      |                   |                  |
| Kencana      | 1.41 b*           | 85.23 ac         |
| Leket        | 4.07 a            | 74.66 a          |
| Lingga       | 5.48 a            | 56.11 b          |
| Cultivations |                   |                  |
| CP**         | 3.80 ab*          | 70.42 ab*        |
| CO           | 4.60 a            | 65.01 b          |
| CF           | 2.57 b            | 80.57 a          |
| R² (%)       | 78.38%            | 68.11            |

* In the column with the same letter are not significantly different according to DMRT at 0.05 level
** CO: Biopesticide Cultivation; CP: Proliga Cultivation; CF: Farmer Cultivation method

3.7. Percentage of weight loss after storage

The interaction treatments between varieties and cultivation methods had a significant effect on the percentage of weight loss of ripe fruit (red) in the storage phase (R²=78.11%) (Table 3), but not significant for mature green fruit. In the storage of mature green chili, the percentage of shrinkage was significantly affected by the treatment of the variety and its cultivation method (R²=88.91%).

Table 3. Percentage weight loss of mature (red) chili fruit after storage

| Interaction Treatment | % weight loss of fruit after storage |
|-----------------------|-------------------------------------|
| CO x Lingga           | 32.423 a**                          |
| CF x Kencana          | 22.507 ab                            |
| CP x Kencana          | 18.373 ab                            |
| CP x Lingga           | 16.548 ab                            |
| CO x Kencana          | 16.036 ab                            |
| CF x Lingga           | 14.743 b                             |
| CO x Leket            | 14.220 b                             |
| CP x Leket            | 12.429 b                             |
| CF x Leket            | 10.197 b                             |

* In the column with the same letter are not significantly different according to DMRT at 0.05 level
** CO: Biopesticide Cultivation; CP: Proliga Cultivation; CF: Farmer Cultivation method

In the storage of red fruit, the lowest and highest shrinkage occurred in Leket and Lingga varieties that was cultivated by CF and CO, respectively; while for mature green, the largest shrinkage was in Kencana variety and CO cultivation method with values of 25.9% and 22.9%, respectively (Figure 8). Low shrinkage in Leket is thought to be due to the thicker skin of the fruit compared to the other two varieties. This is according to research [28], where the shrinkage weight will decrease with the increasing of fruit size.
Figure 8. Percentage weight loss of mature green chili fruit after storage on three chili varieties (a) and three cultivation methods (b). * In the one figure with the same letter are not significantly different according to DMRT at 0.05 level; CO: Biopesticide Cultivation; CP: Proliga Cultivation; CF: Farmer Cultivation method

4. Conclusion
The proliga system of red chili cultivation technology using biopesticide treatment can be applied in the rainy season with a production yield of 161.2% higher than the farmer’s method. The production potential per hectare of the local Leket chili variety reached 14.86 tons; while Kencana and Lingga varieties reached 9.95 tons and 13.05 tons or about 82.2% and 97.4% of their minimum potential production capacity, respectively.

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