Selection of chilli and tomato cultivars for mitigation of climate change and realization of sustainable production

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Abstract. Climate change is inevitable, and vegetables are sensitive to climate change. Thus, cultivars resistant to climate change are alternatives. This study was aimed at examining the adaptation capability of selected lines and varieties of tomato and chilli in farmers’ lands. Five improved lines and varieties of chilli and tomato were selected. The trials were conducted using a randomized block design in upland and lowland to understand the response of selected cultivars in a new agroecosystem. There were three replications at each site. Agronomic aspects were used as performance indicators. The results showed significant differences in each site. Several improved lines of chilli showed better performance than others in high altitude. However, the performance depends on the altitude and season. Lines performed better at high altitude and could not result in the same at low altitude. This is the same case as the tomato. Some lines showed good performance in upland, but they did not show in lowland, and vice versa. Based on the finding, it is recommended that farmers are expected to select the best lines accordingly to the locations they will cultivate tomato and chilli.

1. Introduction
Vegetables, including chilli and tomato, have a high economic value because of its potential use. Both are horticultural commodities that play an important role in the Indonesian economy and they include in the top ten vegetable commodities in Indonesia and have contributed to rural welfare through commercialization [1,2]. As a vegetable, chilli and tomato also provide health benefits to a human being because they contain many vitamins and micro-nutrients [3 4]. In Indonesia, one of the chilli- and tomato-producing areas is East Java province (see figure 1). Chilli dominates the production; meanwhile, tomato is the lowest. Other vegetables are in between tomato and chilli.

Chilli and tomato require serious attention to improve yield and quality. However, chilli and tomato productivity are still lower than the potential because of many factors, including genetic and agronomic technology. Efforts to increase the production in Indonesia facing many obstacles, including lack of high-quality chilli seeds, high yields losses due to pests and diseases, post-harvest handling, and decrease in soil fertility [1,2].

Based on the field observation, low production of chilli and tomato was caused by the limited availability of high-yielding varieties at the farm level, so many farmers are cultivating local varieties of tomato with low-quality seed. The presence of climate change has exaggerated the condition. Climate change is marked by changes in world climate patterns that result in erratic weather phenomena such as extreme air temperatures, frequent storms, and changes in wind direction. The climate change provides
Conducive atmosphere for pests and pathogens to create new strains of fungal, bacterial and viral diseases.

The future challenge is to have sustainability and competitiveness, to fulfil the demand for chilli and tomato that were cultivated on land with decreasing fertility, decreasing water content, and the threat of climate change. These challenging environments require highly site-specific varieties and knowledge to increase the production. Vegetables are generally sensitive to extreme environments. High temperatures and low soil moisture are the main causes of low production. This is because they are seriously influenced by several physiological and biochemical processes such as reduced photosynthetic activity, changes in metabolism and enzyme activity, thermal damage to tissues, and reduced pollination and fruit formation. Thus, the consequences of climate change have negative impact on vegetable production [5]. Increasing chilli production can be done by using high-yielding varieties planted on proper environmental conditions and cultivation technology. Therefore, varieties of chilli and tomato that have been released can adapt to various appropriate altitude and season. This is important because every plant varieties have different characteristics. Thus, it is necessary to examine the adaptation of some selected varieties that have been released by research institutions.

The adoption of resistant varieties is necessary to control disease. It is effective when these varieties are available [7]. Planting resistant varieties not only reduce production costs but also avoid contamination of the environment with toxic chemicals that are used to control the disease [8]. The use of varieties that can adapt and produce high production is an option in the development of tomato and chilli, tomato plants cultivated still dominated by the local varieties. In the lowland, the problems to develop high yield were caused by the varieties that not resistant to high temperatures and bacterial wilt disease. Therefore, the aim of this research is to examine several varieties of chilli and tomato that are resistant and adaptive to the impacts of climate change.

2. Materials and methods

2.1. Study sites and cultivars

This study was carried out during the rainy season of 2015 to 2016 in upland (Village: Semen, Sub-district: Gandusari, Regency: Blitar, altitude: 700 m above sea level), and lowland (Village: Pelem, Sub-district: Pare, Regency: Kediri, altitude: 150 m above sea level). The number of entry consisted of one variety and three lines of tomato; and one variety and four lines of chilli. The selection of varieties and lines were based on varieties that were usually grown by local farmers and the lines having best performance in the previous field trials. Permata and Kencana were the variety of tomato and chilli,
respectively selected for this study. Lines of tomato included CLN3078, CLN3024 and CLN2026; and lines of chilli included AVPP0513, AVPP0514, AVPP1102 and AVPP0708. The World Vegetable Center in Taiwan developed such lines of tomato and chilli.

2.2. Study design
Planting chilli sand tomatoes arranged in a randomized block design with three replications in 20 plots. Each plot containing 20 plants spaced 50 cm plots, each planted with a planting hole chilli seed. Crops were planted at a spacing of 50x50cm. Farmers planted each variety in its own separate plot, with each plot separated by an irrigation channel or other clear separation. Each plot contained 20 plants. Each farmer used his/her usual management practices. However, it is important that each farmer should be consistent within his/her own farm regarding planting distances, plot size, irrigation ditch dimensions and crop management practices, such as fertilizer application, weeding, pest management and irrigation. The plot arrangement is presented in figure 2.

![Plot arrangement of field trials.](image)

Data were compiled in a spreadsheet and analysed using ANOVA. The least significant difference was applied when The ANOVA showed significant difference at a confidence interval of 95% to see the differences among varieties at 5% of significant level.

3. Results and discussion
There were two different results of the study. The first result is that tomato and chilli cultivated in upland, and the second one is those cultivated in the lowland. There is a discussion after the presentation of finding in both upland and lowland.

3.1. Upland
Table 1 shows the performance of tomato cultivated in upland. It can be seen that growth varieties and lines of tomato at the 30 DAT to 60 DAT, on average Permata showed the highest relative to the growth of other lines. Line of CLN3078 level was below 3024. CLN2026 and CLN3078 growth showed an average of lower plant height.

The average number of leaves produced by CLN3024 and Permata varieties also showed considerable amounts at 60 DAP; it was also influenced by the growth of higher plants that formed more leaves. Varieties of Permata showed the most extensive canopy, followed by CLN2026 and CLN3024 which both showed similar canopy size, though wider canopy shown by CLN2026. CLN3078 showed the narrowest canopy, which caused the less photosynthesis process.
Permata also generates an average of more production than other lines in a plot of plants. Production below the Permata is CLN3024 followed by CLN2026 lines. The lowest production resulted by CLN3078. This is related to the process of photosynthesis which is the process of making food in plants. The less photosynthesis process in CLN3078, resulting in the lower production of tomatoes. Permata varieties are more adaptable than AVRDC lines such as CLN3078, 3024 and CLN2026, especially during the rainy season.

Table 1. Agronomic indicators at days after planting and yield of tomato in upland.

| Lines/ Varieties | Plant height (cm) | Number of leaves | Canopy (cm²) | Yield (g plot⁻¹) |
|------------------|-------------------|------------------|--------------|-----------------|
|                  | 30 DAP  | 45 DAP  | 60 DAP  | 30 DAP  | 45 DAP  | 60 DAP  | 30 DAP  | 45 DAP  | 60 DAP  | 30 DAP  | 45 DAP  | 60 DAP  |
| Permata          | 50 a     | 98 a     | 121 a    | 11 a     | 21 a     | 121 a    | 3813 a   | 4730 a   | 6260 a   | 18000 a  |
| CLN3078          | 31 c     | 65 c     | 88 b     | 9 a      | 24 a     | 88 b     | 1956 b   | 2686 b   | 3780 b   | 11000 c  |
| CLN3024          | 41 b     | 85 b     | 114 a    | 10 a     | 29 a     | 114 a    | 3157 a   | 4020 a   | 4240 b   | 16000 b  |
| CLN2026          | 41 b     | 77 bc    | 90 b     | 12 a     | 23 a     | 90 b     | 3000 a   | 4121 a   | 4620 b   | 15000 b  |

Note: Number at the same column followed by different letter indicates a significant difference at 5%; DAP stands for day after planting.

Table 2 shows the performance of chilli cultivated in the upland. Kencana varieties which is an OP (open-pollinated) varieties from IVEGRI showed the highest growth compared to the lines. Kencana level is below 10, which is a hybrid variety commonly grown crop farmers also show growth is quite high compared to the four lines. AVPP0718, AVPP0219 and AVPP1102 presented the lower growth. The lowest production generated by Kencana varieties, this is due to the shorter shape and small size of Kencana varieties, as well as lighter. However, it has the highest number of fruits.

Table 2. Agronomic indicators at days after planting and yield of chilli in upland.

| Lines/ Varieties | Plant height (cm) | Number of leaves | Canopy (cm²) | Yield (g plot⁻¹) |
|------------------|-------------------|------------------|--------------|-----------------|
|                  | 30 DAP  | 45 DAP  | 60 DAP  | 30 DAP  | 45 DAP  | 60 DAP  | 30 DAP  | 45 DAP  | 60 DAP  |
| Kencana          | 25 a     | 45 a     | 86 a     | 27 a     | 57 a     | 228 a    | 527 ab   | 2350 a   | 2463 a   | 3380 a   |
| AVPP0718         | 20 a     | 30 a     | 43 a     | 17 a     | 33 a     | 133 a    | 455 bc   | 1633 b   | 1764 b   | 3540 a   |
| AVPP0514         | 20 a     | 34 a     | 62 a     | 17 a     | 27 a     | 115 a    | 395 cd   | 1691 b   | 1725 b   | 5750 c   |
| AVPP1102         | 18 a     | 31 a     | 58 a     | 14 a     | 32 a     | 128 a    | 620 a    | 1619 b   | 1776 b   | 4300 b   |
| AVPP0719         | 16 a     | 26 a     | 56 a     | 16 a     | 24.6 a   | 123 a    | 387 d    | 1250 c   | 1480 c   | 5030 c   |

Note: Number at the same column followed by different letter indicates a significant difference at 5%; DAP stands for day after planting.

3.2 Lowland

Table 3 shows the performance of tomato cultivated in the lowland. From the observation of high growth of plants known to the average growth of CLN3024 showed the highest growth and almost the same as the varieties used by farmers which varieties of Permata. For the tomato lines showing growth low of CLN2026. Similarly, the number of leaves produced more Permata, and then followed CLN2026 also has a number of leaves that much. For CLN3078 and CLN3024 resulted in a low number of leaves.

Permata and CLN3078’s canopy width was wider than the CLN3024 and CLN. The CLN3024 showed the lowest canopy development than others. For the same output that was produced on the upland, Permata was capable of producing higher compared to most other lines, the level below are CLN2026 and CLN3024. The presence of high temperatures can lead to significant reduction in tomato productivity due to the reduced number, size, and quality of produced fruit [26].

Table 4 shows the performance of chilli cultivated in the lowland. Implementation of the various lines and varieties of chilli on lowland showed that the highest plant growth than other lines allows more...
fruiting branches. Kencana had the highest plant height, then followed by AVPP0514, AVPP1102, AVPP0718 and AVPP0719.

Table 3. Agronomic indicators at days after planting and yield of tomato in lowland.

| Lines/ Varieties | Plant height (cm) | Number of leaves | Canopy (cm²) | Yield (g plot⁻¹) |
|------------------|------------------|-----------------|-------------|-----------------|
|                  | 30 DAP 45 DAP 60 DAP | 30 DAP 45 DAP 60 DAP | 30 DAP 45 DAP 60 DAP | 30 DAP 45 DAP 60 DAP |
| Permata          | 69 a 98 a 125 a 13 a 36 a 43 a 1870 a 2440 b 4540 a 21000 a | | | |
| CLN3078          | 35 b 76 b 112 a 15 a 16 c 22 b 1900 a 3100 a 4680 a 10000 b | | | |
| CLN3024          | 39 b 87 ab 126 a 14 a 19 c 27 b 1360 a 1680 b 2660 b 12000 bc | | | |
| CLN2026          | 41 b 87 ab 101 a 11 a 28 b 39 a 1930 b 2040 c 3060 c 13000 c | | | |

Note: Number at the same column followed by different letter indicates a significant difference at 5%; DAP stands for day after planting.

Table 4. Agronomic indicators at days after planting and yield of chilli in lowland.

| Lines/ Varieties | Plant height (cm) | Number of fruits | Canopy (cm²) | Yield (g plot⁻¹) |
|------------------|------------------|-----------------|-------------|-----------------|
|                  | 30 DAP 45 DAP 60 DAP | 30 DAP 45 DAP 60 DAP | 30 DAP 45 DAP 60 DAP | 30 DAP 45 DAP 60 DAP |
| Kencana          | 46 a 71 a 73 a 0 5 c 25 a 620 ab 2765 a 2898 a 1250 d | | | |
| AVPP0718         | 35 b 55 b 60 bc 0 6 ab 15 ab 555 bc 1921 b 2076 b 1750 c | | | |
| AVPP0514         | 45 a 63 ab 68 ab 0 5 bc 17 ab 465 cd 1990 b 2030 b 2250 a | | | |
| AVPP1102         | 44 a 58 b 63 abc 0 7 a 19 a 729 a 1905 b 2090 b 1250 d | | | |
| AVPP0719         | 34 b 53 b 58 c 0 2 d 4 b 407 d 1370 c 1560 c 2000 b | | | |

Note: Number at the same column followed by different letter indicates a significant difference at 5%; DAP stands for day after planting.

At 45 days after planting, AVPP1102 and AVPP0718 resulted in the faster average number of fruits at 7.4 and 6.4. This indicates that they had a faster flowering period. At 60 days after planting, Kencana was able to generate the highest amount of fruit than the other lines. It is associated with higher plant height so that it has potential to form more fruit. Kencana was also capable of forming wider canopy than other lines followed by AVPP1102, 0718, AVPPAVPP0514, and AVPP0719.

The highest production per plot was on AVPP0514 followed by AVPP0719 and AVPP0718. They were able to generate higher production compared with Kencana varieties. AVPP1102 and Kencana had the lowest production, due to the small size of Kencana fruits, while AVPP1102 had a fairly large fruit size but a smaller number of fruits. High temperatures did not affect the stage before flowering in chilli, namely the viability of the pistil or stamens. However, high temperatures during post-pollination will inhibit fruit formation, where the fertilization process is sensitive to high-temperature stress. High temperature also affects the development of red color in ripe chilli and also causes flowers to fall, seeds that fall out, low fruit formation and loss of chilli [9].

3.3. Discussion

From the results of the field trial, there was no certain lines and varieties of chilli and tomato showing consistent performance both in upland and lowland simultaneously. Several lines performed well in upland and not good in lowland, and vice versa. This indicates that every line and variety have a special and specific response to the condition of the agroecosystem. These findings support a proposition that vegetables, including chilli and tomato, are sensitive to the environment. For example, chilli will grow well in areas that have up to 900 m above sea level, the soil with much organic matter, pH of 6 to 7, crust soil texture [10]. Changes in such environment affect the performance.

Well-adapted varieties, if these varieties are composed of a number of genotypes that have the ability to adapt to differences in environmental conditions. This is due to wide variety of genotypes having genetic make-up that enable to control the morphology and physiology to adapt to particular environment or environmental change [11]. It is understandable to us that specific environmental
differences have a profound effect on some genotypes. A certain genotype A may be superior to genotype B in X environment, but inferior in the Y environment. Thus, each chilli variety or line will certainly give different results when planted in different agroecosystems. The use of superior and high quality seeds are necessary to obtain profitable crop production economically. Conversely, the use of low-quality seeds will produce low percentage of occurrence of seedling and less tolerant of abiotic stresses, more sensitive to plant diseases, as well as a negative impact on quality and yields of crops. It is strongly recommended for farmers to adopt the suitable lines and varieties of chilli and tomato to the locally specific environment. It should be supported by scientists to continually develop genetic technology to discover new lines that have adaptive capacity to climate change. This is very important because by adopting the improved and developed lines combined with good agricultural practices are potential on improving rural livelihoods [12].

4. Conclusions
From the field trials conducted in two different altitudes: upland and lowland, can be concluded as follow. Tomato Permata varieties showed the best performance due to the highest production compared to the alternative CLN2026 and CLN3024. However, CLN2026 showed good performance when planted on slightly rainy conditions. Overall, tomato lines showed better performance when cultivated in the upland than lowland. For chilli, Kencana varieties produced the highest amount of fruit, but the size of fruit was smaller and shorter than others. This caused low production in terms of wight. Lines of chilli that showed high production at both upland and lowland were AVPP0514 and 0513 AVPP.

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