# Growth and yield of temulawak (*Curcuma xanthorizha Roxb.*) and corn (*Zea mays* L.) with various intercropping patterns

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## Abstract

Temulawak is rarely cultivated with any intensity because it has a long harvest time and requires wide spacing. One of the solutions for temulawak cultivation is through applying intercropping systems with corn. The current research aimed to determine the most advantageous intercropping planting pattern of temulawak and corn. The experiment adhered to a randomized block design with six treatments and four replications. The treatments were: $T_1$ = strip cropping; $T_2$ = row cropping; $T_3$ = strip-relay temulawak-corn; $T_4$ = row-relay temulawak-corn; $T_5$ = strip-relay corn-temulawak; and $T_6$ = row-relay corn-temulawak. The results showed that different cropping patterns of an intercropping system of temulawak and corn affected the growth and yield of both crops. The most suitable polyculture cropping pattern, based on land equivalence ratios (LER) values and R/C ratios, was strip cropping that produced rhizhomes of temulawak of up to 2.68 ton ha$^{-1}$ and of corn of up to 5.24 ton ha$^{-1}$. The LER value was 1.22 and the revenue/cost (R/C) ratio was as much as 1.43 with a net profit of as much as IDR 9,509,000.

## Introduction

Temulawak (Curcuma) (*Curcuma xanthorriza* Roxb.) is a medicinal plant native to Indonesia that is required in large quantities to produce traditional medicines, but the amount of rhizome material supply is still very low. This is because temulawak is not cultivated intensively. Intensive Curcumais cultivated under monoculture cropping regimes, usually with wide planting (100 × 50 cm) and the time of harvest is rather long at approximately nine to12 months,[1] so there is much empty land that is not utilized, rendering farmers reluctant to cultivate temulawak. Therefore, to take advantage of existing land resources and increase farmer incomes, temulawak can be intercropped with food crops that have a shorter life span, like corn. Corn can be intercropped with temulawak because it has a shorter harvest time of roughly three to four month and a relatively narrow spacing of 50 × 25 cm.[2,3] In addition, temulawak and corn have somewhat different growth phases, and this reduces resource competition, such that for soil nutrients, soil moisture, and sunlight.

Intercropping systems can usually increase total yield per unit area of land, but with this cropping system, competition might arise among the major crops – intercrops could result in decreasing crop productivity. The critical period is one of the factors that determine the success of intercropping systems because it affects plants' abilities to compete with others.[4] Hence, it is necessary to find a suitable model intercropping system to minimize the effects of competition and maintain crop productivity.

## Materials and Methods

This research was conducted at the field experiment station of the Faculty of Agriculture, Jatikerto village, subdistrict of Kromengan, Malang at 300 m above sea level. The average air temperature was 13-31°C, average annual rainfall was 1500-5000 mm, and the soil was of the Alfisols variety. The study began in February and lasted until September 2015.

The planting material used in this study was the temulawak clone of UB2 and seeds of hybrid corn, along with urea (46% N) 300 kg.ha$^{-1}$, SP-36 (36% P2O5) 100 kg.ha$^{-1}$ and KCl (50% K2O) 150 kg.ha$^{-1}$ as sources of nutrient N, P, and K, respectively. The temulawak rhizome was employed as a seed and germinated first. Once the shoots appeared, the rhizomes were cut, leaving one bud with a fresh weight of nearly 10 g/seed, and this rhizome seed was maintained until 5 cm long shoots indicated seedlings were ready for planting in the field. Rhizome seedlings were planted such that the shoots emerged above the soil surface. Corn seeds were planted in planting holes, two seeds per hole.

This study used a RBD with four replications and six cropping patterns, namely: $T_1$ = strip cropping, $T_2$ = row cropping, $T_3$ = strip-relay temulawak-corn, $T_4$ = row-relay temulawak-corn, $T_5$ = strip-relay corn-temulawak, and $T_6$ = row-relay temulawak-corn. Strip-cropping patterns emanate from planting row crops alternately with other row crops, while row cropping is planting two species alternately in the same row. In terms of strip cropping ($T_1$) and row cropping ($T_2$), temulawak and corn crops were grown simultaneously. For strip-relay cropping of temulawak-corn ($T_3$) and row-relay cropping of temulawak-corn ($T_4$), corn was planted four months after temulawak. With regards to the strip-relay cropping of corn-temulawak ($T_5$) and row-relay cropping of corn-temulawak ($T_6$),the temulawak crop was planted four weeks after corn. The planting space for temulawak was 100 cm × 50 cm, for corn was 50 cm × 25 cm, and for temulawak-corn was 50 cm × 25 cm.

Observations on temulawak plants focused on plant length, a number of leaves, and leaf area as well as rhizome yield per hectare, whereas the corn parameters were planted length, the number of leaves, leaf area and corn cobs per hectare. Temulawak rhizomes were harvested at the age of six months after planting (MAP) and corn cobs were harvested 110 days following planting. To assess the benefits of intercropping systems, the LER was used with the formula:[5]

$$LER = Ax/Ay + Bx/By$$

Ax = yield of crop A with the intercropping system; Ay = yield of crop A in a monoculture system; Bx = yield of crop B in an intercropping system; and By = yield of crop B in a monoculture system.

The resulting value of the LER is a ratio indicating the amount of land needed to grow both crops together compared to the proportion of land required to grow pure stands of each crop. AnLER > 1.0 usually means that the intercropping system is of

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value, whereas anLER < 1.0 refers to a disadvantageous system.

The efficiency of farming systems can be estimated by the value of the revenue/cost (R/C) ratio. It is the total revenues divided by total costs or can be expressed with the equation:[6]

$$R/C = P_Q . Q / (TFC+TVC)$$

R = revenue; C = cost; $P_Q$ = price of output; Q = quantity of products; TFC = total fixed costs; and TVC = total variable costs.

Data analysis leveraged the analysis of variance (ANOVA) method. If there was a significant difference between the treatments, the advanced analysis was carried out with the least significant difference (LSD) test at P=0.05.

## Results and Discussion

### Temulawak plant growth

The length of plants was one of the main variables for plant growth. Temulawak plants grow longer when planted with strip cropping, row cropping, strip relay (temulawak-corn) cropping and row-relay (temulawak-corn) patterns (Table 1). This is because the cropping patterns minimize competition between temulawak and corn. Corn can shade the temulawak plant, so sunlight received by temulawak is reduced and etiolation occurs. This is consistent with the results of others,[7] light intensity is lower at a 75% shade treatment, stimulating etiolation and extending leaves' petioles.[8,9] The relay cropping of corn-temulawak was the cropping pattern that led to the growth of temulawak being the most constrained versus the others. This was because temulawak plants could not compete with the corn that was planted earlier.[10,11] The critical period of a plant usually is during the first 25-33% of its life cycle, or 1/4-1/3 of its early age.[4] For corn growing, this critical period takes place at the age of 0-1 months, while the temulawak critical period is at 0-3 months. Leaves serve as the main organ for photosynthesis in corn and temulawak. Leaf surface area, with high chlorophyll content, can improve the capture of sunlight for such photosynthesis. It was found that the number of leaves (Table 2) and leaf area (Table 3) was most pronounced during the growing season of the crop.

**Table 1. Plant length of temulawak.**

| Cropping patterns | Plant length (cm) at different age: (WAP) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
| T1 = Strip cropping | 27.81 b | 44.00 b | 64.04 b | 80.29 b | 88.12 b | 90.00 b | 92.47 b |
| T2 = Row cropping | 18.21 a | 27.67 a | 42.33 a | 67.25 b | 75.63 b | 77.21 b | 80.29 b |
| T3 = Strip relay (T-J) | 22.67 ab | 31.25 ab | 50.62 ab | 73.75 b | 79.06 b | 81.67 b | 83.56 b |
| T4 = Row relay (T-J) | 27.81 b | 34.17 ab | 51.35 ab | 73.75 b | 74.43 b | 83.64 b | 85.04 b |
| T5 = Strip relay (J-T) | 22.62 ab | 40.42 b | 46.25 ab | 47.58 a | 53.33 a | 55.81 a | 58.12 a |
| T6 = Row relay (J-T) | 23.87 ab | 43.37 b | 55.54 b | 57.75 ab | 59.87 ab | 60.75 ab | 62.75 ab |
| LSD 5% | 6.34 | 10.31 | 11.47 | 16.63 | 20.10 | 21.22 | 21.62 |
| CV (%) | 20.61 | 21.67 | 17.20 | 19.31 | 21.71 | 21.96 | 21.74 |

*N, numbers followed by the same letter are not significantly different (LSD 5%).

**Table 2. Leaves number of temulawak at various cropping patterns.**

| Cropping patterns | Leaves number (cm) at different age: (WAP) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
| $T_1$ = Strip cropping | 2.75 | 4.25 b | 6.00 b | 7.75 b | 9.00 b | 9.50 b | 9.25 b |
| $T_2$ = Row cropping | 2.50 | 3.25 a | 4.75 a | 7.50 b | 8.50 b | 9.00 b | 9.25 b |
| $T_3$ = Strip relay (T-J) | 2.50 | 3.75 ab | 6.00 b | 7.75 b | 8.50 b | 9.25 b | 9.25 b |
| $T_4$ = Row relay (T-J) | 2.75 | 4.25 b | 6.50 b | 8.25 b | 9.17 b | 9.25 b | 9.25 b |
| $T_5$ = Strip relay (J-T) | 2.50 | 4.50 b | 5.25 ab | 5.75 a | 7.00 a | 7.50 a | 7.50 a |
| $T_6$ = Row relay (J-T) | 2.75 | 4.50 b | 5.25 ab | 6.50 a | 7.50 a | 7.75 ab | 8.75 ab |
| LSD 5% | tn | 0.79 | 0.82 | 1.21 | 0.76 | 1.49 | 1.54 |
| CV (%) | 25.97 | 15.05 | 11.31 | 13.01 | 10.69 | 13.30 | 13.48 |

*N, numbers followed by the same letter are not significantly different (LSD 5%).

**Table 3. Leaf area of temulawak under various cropping patterns.**

| Cropping patterns | Leaf area ($cm^2$) at different age: (WAP) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
| $T_1$ = Strip cropping | 156.86 b | 401.79 b | 787.51 b | 1199.26 b | 1439.56 b | 1741.45 b | 1561.69 b |
| $T_2$ = Row cropping | 82.46 a | 211.72 a | 556.02 ab | 947.29 b | 1433.08 b | 1534.03 b | 1839.75 b |
| $T_3$ = Strip relay (T-J) | 102.93 a | 291.65 ab | 699.80 b | 1229.90 b | 1625.78 b | 1933.36 b | 2046.39 b |
| $T_4$ = Row relay (T-J) | 121.58 a | 341.80 b | 790.50 b | 1242.75 b | 1858.46 b | 1952.81 b | 1975.83 b |
| $T_5$ = Strip relay (J-T) | 88.80 a | 220.34 a | 437.87 a | 569.45 a | 727.57 a | 811.02 a | 827.17 a |
| $T_6$ = Row relay (J-T) | 96.46 a | 277.80 ab | 537.22 ab | 805.5 ab | 977.2 ab | 1159.0 ab | 1178.8 ab |
| LSD 5% | 40.87 | 103.90 | 235.22 | 330.35 | 581.95 | 653.73 | 529.11 |
| CV (%) | 29.26 | 30.33 | 28.70 | 25.61 | 22.08 | 22.63 | 26.07 |

*N, numbers followed by the same letter are not significantly different (LSD 5%).

The number of leaves and leaf area for temulawak was higher with the strip-cropping, row-cropping, strip-relay, and row-relay (temulawak-corn) patterns; temulawak under a strip-relay cropping (temulawak-corn) pattern produced the fewest leaves (Table 2). Any plant that grows longer typically produces more leaves, and shorter plants usually possess fewer leaves.[12] This is supported by previous studies that have observed more leaves are formed in longer-growth plants, so therefore the total leaf area of plants increases and the ability of plants to produce biomass is also enhanced.[7,13]

## Growth of corn

The strip-cropping and row-relay cropping (temulawak-corn) patterns yielded a corn plant that was longer than all other planting patterns (Table 4). This maybe because, with the row-relay and strip-relay (temulawak-corn) patterns, the young corn plants suffered from the shading of temulawak that had been grown in advance, so the young corn experienced etiolation. For the strip-relay and row-relay (temulawak-corn) patterns (Table 4), corn plants exhibited a normal average plant length of 195.62 cm [strip-relay (temulawak-corn)] and 190.33 cm [row-relay (temulawak-corn)], respectively. These corn plant lengths of corn were considered *normal* for hybrid corn of pertiwi-3.[14]

The number of leaves and corn leaf area increased with the age of the plant. Strip-cropping and row-relay (temulawak-corn) patterns led to higher numbers of leaves (Table 5) and greater leaf area (Table 6) than the other planting patterns. The row-relay and strip-relay (temulawak-corn) patterns produced corn with fewer leaves number and diminished leaf area. This seemed to be related to the corn plant length. The strip-cropping and row-relay (temulawak-corn) patterns resulted in a longer plant than other cropping patterns (Table 4), in turn featuring more leaves (Table 5) and larger leaf surface areas (Table 6). On the contrary, the strip-relay

**Table 4. Plant length of corn under various cropping patterns.**

| Cropping patterns | Plant Length (cm) at different age: (week after planting, wap) | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| $T_1$ = Strip cropping | 22.10 a | 59.70 b | 144.58 b | 204.50 ab |
| $T_2$ = Row cropping | 16.94 a | 41.17 a | 115.87 a | 188.00 a |
| $T_3$ = Strip relay (T-J) | 54.33 b | 103.58 c | 181.00 b | 270.87 b |
| $T_4$ = Row relay (T-J) | 50.96 b | 100.54 c | 170.17 b | 264.04 b |
| $T_5$ = Strip relay (J-T) | 20.42 a | 45.35 ab | 122.87 a | 195.62 a |
| $T_6$ = Row relay (J-T) | 19.82 a | 43.01 ab | 127.62 a | 190.33 a |
| LSD 5% | 9.75 | 17.43 | 43.54 | 62.74 |
| CV (%) | 21.04 | 17.47 | 20.11 | 19.03 |

*N, numbers followed by the same letter are not significantly different (LSD 5%).



**Table 5. Leaves number of corn under various cropping patterns.**

| Cropping patterns | Leaves number at different age: (wap) | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| $T_1$ = Strip cropping | 2.75 a | 6.00 a | 10.75 ab | 14.16 ab |
| $T_2$ = Row cropping | 2.50 a | 5.50 a | 10.25 a | 14.16 ab |
| $T_3$ = Strip relay (T-J) | 3.58 ab | 7.92 b | 12.92 b | 16.00 b |
| $T_4$ = Row relay (T-J) | 4.5 b | 7.87 ab | 12.50 b | 16.00 b |
| $T_5$ = Strip relay (J-T) | 3.12 a | 6.50 a | 10.25 a | 13.83 a |
| $T_6$ = Row relay (J-T) | 2.92 a | 6.37 a | 10.25 a | 13.67 a |
| LSD 5% | 1.09 | 1.72 | 1.84 | 1.88 |
| CV (%) | 22.44 | 17.11 | 10.92 | 8.55 |

*N, numbers followed by the same letter are not significantly different (LSD 5%).

**Table 6. Leaf area of corn under various cropping patterns.**

| Cropping patterns | Leaf area ($cm^2$) at different age: (wap) | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| $T_1$ = Strip cropping | 34.42 a | 338.98 a | 1998.36 a | 3347.13 ab |
| $T_2$ = Row cropping | 23.44 a | 270.83 a | 1788.88 a | 3156.00 ab |
| $T_3$ = Strip relay (T-J) | 93.09 b | 1475.85 b | 3065.76 b | 3862.55 b |
| $T_4$ = Row relay (T-J) | 112.46 b | 1251.90 b | 2810.40 b | 3519.96 b |
| $T_5$ = Strip relay (J-T) | 30.36 a | 324.06 a | 1997.88 a | 3144.95 ab |
| $T_6$ = Row relay (J-T) | 33.43 a | 259.42 a | 1732.88 a | 2854.94 a |
| LSD 5% | 17.79 | 248.41 | 686.69 | 588.99 |
| CV (%) | 21.66 | 25.23 | 20.42 | 11.79 |

*N, numbers followed by the same letter are not significantly different (LSD 5%).

and row-relay (temulawak-corn) patterns yielded corn plants that were shorter (Table 4) compared with other cropping patterns, with fewer leaves (Table 5) and smaller leaf surface areas (Table 6). These findings are consistent with those of previous studies.[7,12,15]

### Yield of temulawak rhizomes

Yields of temulawak rhizomes were highest for the row-cropping patterns, while the lowest rhizome yields were observed with the row-relay and strip-relay (temulawak-corn) patterns (Figure 1). This was most likely because row cropping was able to produce more biomass and rhizomes.[16,17] In addition, the critical period of temulawak plants also affected the growth and yield of rhizomes.[4] Corn planted one month earlier passed their critical period (age 0-1 months) and was ready to compete with curcuma planted a month later, while newly planted curcuma were still in their critical period (0-3 months), requiring more resources to support their initial growth.[18] This situation means the growth of temulawak via the strip-relay and row-relay (temulawak-corn) was inhibited, leading to lower yields of rhizomes than other cropping patterns.[19,20] This is different from the row cropping of temulawak and corn, where the critical period of both crops are at the same time, so there is no effect from the dominance of other plants in terms of obtaining soil water, soil nutrients, and sunlight to meet their needs.[21-24]

### Yield of corn

Higher yields of corn cobs were obtained with the strip-relay (temulawak-corn) pattern, while there were lower yields for the row-cropping and row-relay (temulawak-corn) patterns (Figure 2). This is probably based on the strip-relay pattern producing longer corn, more leaves, and a greater leaf surface area results in increased biomass and higher dry weights of corn cobs per hectare. This scenario would be completely reversed in the case of shorter crops.

One of the most important factors influencing crop growth is the production of biomass and its sink capacity.[15] Other factors that may also impact plant growth and corn yield are soil disturbances from temulawak planting activities at a time when corn is four weeks of age, especially any perturbation of corn root growth. If the roots of young corn plants are disrupted, the absorption of nutrients and soil moisture are also interferred with, leading to lesser corn growth and yield.[25,26]

### Land equivalent ratio (LER)

The cropping patterns with the best LERs values were strip cropping (1:22), strip relay (temulawak-corn) (1.14), and row cropping (1.07). The other cropping patterns appeared to be inferior with lower LER values, namely strip relay and row-relay (temulawak-corn) at 0.67 and 0.47, respectively**.** AnLER≈2.0 was suggestive of more efficient cropping patterns in terms of employment of land resources. Conversely, if a value for LER < 2.0, the cropping pattern would be deemed less efficient.[5] Results from various studies have indicated that intercropping systems involving appropriate species can lead to higher total productivities and greater LER.[27-34]

### Economic analysis of farming systems

From the calculation of the R/C ratio for all cropping patterns studied here, it was established that the non-feasible cropping patterns were the row-relay (temulawak-corn) and strip-relay and row-relay (temulawak-corn) patterns, with R/C ratios of 0:91, 0:84, and 0:58, respectively. If the value of an R/C ratio > 1, the farming systems are considered economically viable, but if the value of an R/C ratio < 1, then

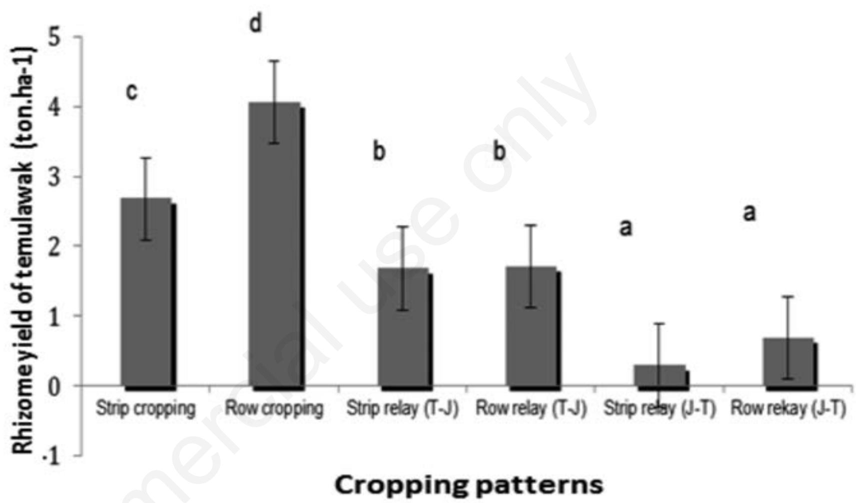


**Figure 1. Rhizome yield of Temulawak per hectare: a graph that accompanied the same letter for each treatment showed notsignificantly different (LSD 5%).**

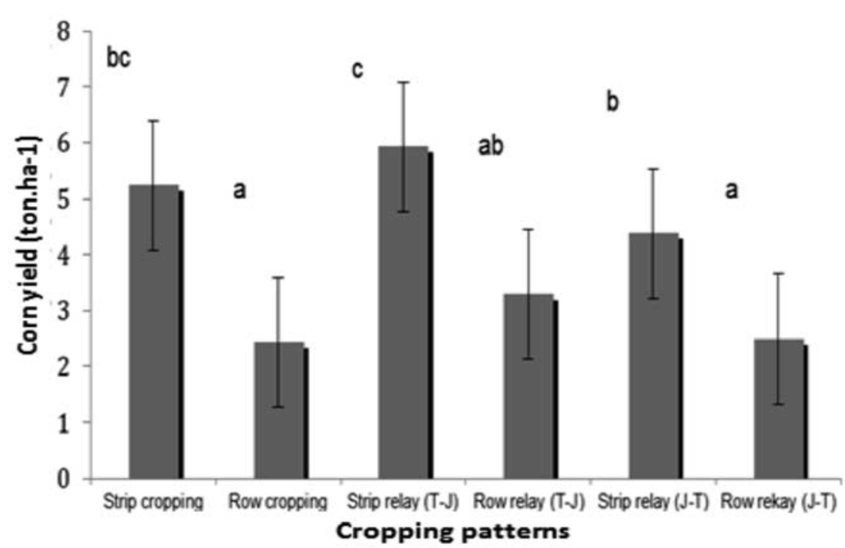


**Figure 2. Yield of corn per hectare: a graph that accompanied the same letter for each treatment showed notsignificantly different (LSD 5%).**

farming systems are deemed economically inviable.[6,35]

Upon further analysis, the strip-cropping, row-cropping, strip-relay, and row-relay patterns had the highest R/C ratio values than the other cropping patterns. However, when viewed from the perspective of net profit, the most lucrative cropping patterns are generally strip-cropping patterns.[36-39] Strip cropping of temulawak-corn can produce approximately 4.65 tons of rhizome ha$^{-1}$ and 2.42 tons of corn cobs ha$^{-1}$, with a net profit greater than all other planting patterns, specifically Rp 9.509 million ha$^{-1}$ with an R/C ratio of 1.43.

## Conclusions

The most efficient intercropping pattern in terms of making use of land resources was strip cropping, which can produce temulawak rhizomes at 2.68 tons ha$^{-1}$ and corn cobs at 5.24 ton ha$^{-1}$ with an LER of 1.22 and an R/C ratio of 1.43; the net profit was Rp 9.509.000 ha$^{-1}$.

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