Compatibility of variety and planting pattern of Maize (*Zea mays*) in early *Ganitri* (*Elaeocarpus ganitrus* Roxb.) based agroforestry in dry land

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Abstract. Agroforestry in dry-land is an effort to increase land productivity and to support food security program. Practicing the proper agroforestry in the early age is very essential not only to optimize the annual crop yield but also giving benefit to the tree growth. *Ganitri* (*Elaeocarpus ganitrus* Roxb.) is a tree species that produce beads with high economic value for religious purpose in Southeast Asia and India. Meanwhile, maize is one of staple food throughout Southeast Asia which support food security program. This research aimed to discover the suitable maize variety and planting pattern for early agroforestry in order to get optimum yield and able to support *ganitri* growth as the main tree. Randomized block design with split plot design was conducted with 2 factors and 3 replications. The main plot was maize variety (single cob and double cobs) and the sub-plot was the planting pattern (two rows and three rows of maize in *ganitri* alleys). The hypothesis of this research was maize varieties and planting pattern in *ganitri* based agroforestry had influence on maize production and the growth of *ganitri*. The result shows that interaction between maize variety and planting pattern have significant effect on the average height of maize in the early and end of growth, nevertheless it does not give any significant response on the early growth of *ganitri* except for the branch number. The utilization of double cobs variety with three rows of maize in between trees gave higher yield, 4.55 t ha\(^{-1}\) dry kernels in total. This planting pattern has the potency to be applied in order to optimize the land-use on early *ganitri*-based agroforestry in dry land.

Keywords: Early agroforestry, maize, *ganitri*, dry-land

1. Introduction

In general, deforestation and forest degradation are caused by the low welfare condition of the community surrounding the forest area, limited access to utilize forest resources, tenurial conflicts which often lead to land acquisition, and the imbalance wood supply-demand which affects national timber industry stability [1]. Forest loss and degradation causes direct and indirect problems related to food insecurity. Direct problems such as the effect of forest loss and degradation on reducing the availability and productivity of fruit producing trees and alternative food source trees. Indirect problems such as ecological factors alterations which has important roles on changing the production of agricultural crops and livestock feed [2].

Forest degradation which worsened by the decreasing number of fertile and productive land area caused the bigger urgency to actualize food independency and security [3]. Agroforestry development
model has good prospects in contributing to increase food production and farmer’s income, thereby facilitating access to food in addition to maintain forest security and preservation with the community or farmers around the forest [4]. On one hand, agroforestry can produce food and on the other hand it is expected to be able to improve the quality of the soil and the environment so that agroforestry can synergize the agriculture, forestry, and ecology [5].

Land utilization under the community forest with agroforestry pattern have the opportunity to enhance food crops development [6]. Silviculture techniques on agroforestry has the potency to be applied to improve dry-land productivity on community forest [7]. Ganitri is a potential species to be planted in agroforestry pattern which is mainly developed in West Java and Central Java [8], [9]. Ganitri is a local name of Elaeocarpus ganitrus Roxb. or also known asjenitri [10] or rudraksh which distributed throughout Nepal, India and southeast Asia [11]. Ganitri produces high economic value fruits with ornate woody rounded endocarp which commonly use as beads for religious jewelery [12]. Several commodities which combined in ganitri-based agroforestry remarkably varied such as crops, medicinal plant, and tubbers. One sort of crop that widely cultivated as the lower crop in ganitri-based agroforestry is maize (Zea mays). Maize is a staple crop that can be functioned as buffer food source in supporting national food security, even though the productivity has not met the national needs [13]. More than that, the development of new superior varieties of maize plays an essential role in the efforts to increase national production [14].

The development of agroforestry in community forests’ dry land area faces some constraints such as water stress, critical land, tree shades, and soil acidity level [7]. Given that maize require a large amount of light, the practice of agroforestry is potential to be undertaken on the early phase since it still has quite wide-open tillage-able area at around 50% [15]. Research showed that the growth and productivity of maize were significantly affected by the spacing and variety [16]. The difference of maize production occurred on different hybrid varieties [15] and between hybrid varieties and local varieties which were planted in agroforestry pattern [7]. According to [17] the maize production in agroforestry pattern was decreasing as getting closer to the tree strips. On the early phase of agroforestry, tree would considered maize as a competitor especially in capturing sunlight [18].

Based on the matters above, to ensure optimum yield and give beneficial influence on the growth of the main trees, the proper arrangement of maize planting pattern and the cultivation of varieties that suitable with the planting site condition are needed. The superior varieties are competent to overcome abiotic stress and to adapt to some of sub-optimal environment states [19]. This study aimed to observe the suitable maize variety and planting pattern on early phase of agroforestry to achieve optimum yield and support the growth of ganitri.

2. Materials and Methods

2.1. Location
This research was conducted in Raksabaya Village, Cimaragas District, Ciamis Regency, West Java which located between 07°23’05,2” S and 108°28’01,0” E with elevation 140 m asl. The study was held on March to July 2018. The ganitri stands was 2 months old with 2 m x 3 m spacing. The soil’s physical and chemical attributes on the research site with the depth of 30-40 cm [20] is presented on Table 1.
Table 1. The soil physical and chemical properties at experimental site

| No. | Parameters                          | Values        | Statue      |
|-----|------------------------------------|---------------|-------------|
| 1.  | Chemical properties:               |               |             |
|     | - pH H₂O                           | 4.98          | Acid        |
|     | - C (%)                            | 2.94          | Moderate    |
|     | - total N (%)                      | 0.26          | Moderate    |
|     | - C/N ratio                         | 11.46         | Moderate    |
|     | - P available (ppm)                | 0.64          | Very Low    |
|     | - Ca (me%)                         | 1.83          | Low         |
|     | - Mg (me%)                         | 0.35          | Low         |
|     | - K (me%)                          | 0.56          | High        |
|     | - Na (me%)                         | 0.38          | Low         |
|     | - Cation exchange capacity (me%)   | 14.96         | Low         |
|     | - Base saturation (%)              | 20.86         | Low         |
| 2.  | Texture:                           |               |             |
|     | - Sand (%)                         | 8.15          |             |
|     | - Dust (%)                         | 26.01         |             |
|     | - Clay (%)                         | 65.84         |             |

Source: Analysis result

2.2. Research Design
This research used 2 varieties of hybrid maize namely single cob (Bisi-18) (V1) and double cobs (Bisi-2) (V2). The design was randomized block design with split plots and 5 replications. The main plot was maize variety and the sub-plots were maize planting pattern (P) included P1 (2 rows of maize within tree row with population 16.167 plants/ha) and P2 (3 rows of maize within tree row with population 24.250 plants/ha). The maize cultivation was using alternate rows planting pattern.

2.3. Plant Preparation
Land preparation consisted of weeding and making lines of tillage-able area between ganitri strips. The line of maize was made at the 3-meter spacing. The width between maize’s row was adjusted to the number of maize rows. Spacing between maize were 50 cm x 40 cm so the distance between maize and ganitri on 2 rows planting pattern was 125 cm and on 3 rows planting pattern was 75 cm. The maize seeds were soaked in water for 2 hours and given fungicide. Plant holes were 5 cm depth and filled with 2 seeds per hole. Organic fertilizer (5 t ha⁻¹) and chemical fertilizer (150 kg ha⁻¹ urea, 50 kg ha⁻¹ TSP, and 25 kg ha⁻¹ KCl) were used [20]. Plant maintenance included weeding, piling up soil around the plants, and pest-disease control. Manual weeding was done by pull out the weeds at every time the weeds emerge. Pilling up the soil was done once when the maize reached 21-28 days after planting [21]. Pest and disease control were done by using pesticide Decis 25 EC. Harvesting was done after the cobs mature with morphological characteristics of ripen kernel, marked by dry and light-brown colored husk leaves with shining kernels and black layer on the base of the kernels.

2.4. Morphophysiological Data Collection
Observed maize parameter were plant’s height, cob’s length, cob’s diameter, plant’s dry weight, dry kernel weight, and harvest index. Plant height was measured at 3; 6; 9 and 12 weeks after planting on
16 samples. The sample number for measuring cob’s length, cob’s diameter, plant’s dry weight and harvest index was 3 plants per plot. Maize dry weight was measured by chopping the stover then put in to oven on 60°C for 48 hours until it reached constant weight. The maize yield was measured based on the dry kernel’s productions. The dry kernels were sampled on 8 plants. Kernels were taken off from the cob’s pith then dried until it reached 14% water content [16]. The conversion of kernels yields to hectare was measured using formula: Kernels yields ha\(^{-1}\) = tillage-able area/hectare (m\(^2\)) x plant population x production of dry kernels/plant. Harvest Index (HI) was measured based on economic dry weight/ total dry weight [22]. Meanwhile, *ganitri* growth measurement included total height, stem diameter and branch number.

2.5. Micro Climate Condition Measurement

Micro climate observation was done with 3 replications per plot, consisted of: light intensity, temperature, air humidity and soil moisture. Light intensity was measured using luxmeter under *ganitri* shade and open area. Temperature and air humidity (RH) were measured using Psychrometer.

2.6. Data Analysis

Data were analyzed using analysis of variance (ANOVA) to discover the difference on the plant response on different treatments and also interaction between treatments. If significant, this test then followed by Duncan multiple range test (DMRT) on \(\alpha = 0.05\).

3. Results and Discussion

3.1. Micro Climate Characteristics

Micro climate characteristics under *ganitri* rows were generally similar for all observed parameters, on each treatment. The result of micro climate condition measurement was presented on Table 2.

| Treatments | Parameter          |          |          |
|------------|--------------------|----------|----------|
|            | ICR (%)            | T (°C)   | RH (%)   |
| V1 x P1    | 61.01 ± 10.03      | 27.58 ± 0.63 | 77.59 ± 3.03 |
| V1 x P2    | 62.92 ± 8.62       | 27.77 ± 0.35 | 74.76 ± 3.02 |
| V2 x P1    | 61.33 ± 21.98      | 26.47 ± 2.07 | 75.83 ± 2.80 |
| V2 x P2    | 63.98 ± 14.09      | 27.73 ± 1.17 | 75.99 ± 1.60 |

Remarks: V1: single cob variety; V2: double cobs variety; P1: 2 rows of maize per tree alley; P2: 3 rows of maize in between tree rows

Table 2 shows that the micro climate condition within row of trees which consisted of light intensity, air temperature and relative humidity were not significantly different between treatments. This was caused by the *ganitri*’s canopy condition which still in its early development and almost the same for all plots. The shade’s effect was not significant due to the stand has even age and still in the early stage. [23] mentioned that sunlight intensity which absorbed by maize plants was influenced by the spacing and interaction between maize spacing and the age of the palm trees. The amount of sunlight reaches the forest floor associates with the air temperature and air humidity condition around the maize planting area. [24] stated that the fluctuation of light intensity tends to fluctuate air temperature, air humidity and soil moisture. As the tree grow older, the canopy coverage increases and so as the shade intensity. This
condition also happened on sengon (*Paraserianthes falcataria*), different the stand age may cause the micro climate conditions are distinctive [25].

In early agroforestry, when *ganitri* was still in its young age (3 months) the micro climate condition has not been showing any significant difference. According to [26], the range of light intensity on the initial phase of agroforestry was at the optimum level for the growth of the intercrop plants such as maize, peanut, and ginger. The enlarging tree canopy can provide positive implications to the lower crop’s growth. Tree canopy can become the buffer against extreme climatic conditions through modification of microclimate components such as solar radiation, air temperature, air humidity, soil temperature and wind velocity [27], [28]. On the other way, the low light intensity can give negative implications by obstructing the biomass development [29] and lower crop growth [30]. Maize grown in agroforestry pattern had higher growth and yield at the early phase compared to middle phase and late phase [26]. In addition to the influence of tree shade, the amount of sunlight which accepted by the maize planted in agroforestry pattern was also determined by the row position and row direction/orientation [18].

3.2. Growth Response and Maize Yield
Above and underground resource dynamics can be discovered by observing the crop response in catching and utilizing the resource which can be seen from the crop productivity [13]. The observation result of the maize height growth on early phase of *ganitri* based agroforestry can be seen on Table 3.

### Table 3. The average maize height on different varieties and planting pattern on *ganitri* based agroforestry.

| Variety      | Planting Pattern (rows between trees) | Height Growth (cm) on (weeks after planting) |
|--------------|----------------------------------------|---------------------------------------------|
|              |                                        | 3   | 6   | 9   | 12  |
| Single cob (V1) | Two rows (P1)                          | 83.19 ab | 159.48 | 166.54 | 186.46 ab |
|              | Three rows (P2)                        | 74.38 b  | 160.77 | 171.04 | 178.54 b  |
| Double cobs (V2) | Two rows (P1)                          | 76.69 ab | 157.29 | 170.31 | 182.29 ab |
|              | Three rows (P2)                        | 89.83 a  | 161.29 | 178.75 | 187.81 a  |
| Mean         |                                        | 81.02 | 159.71 | 171.66 | 183.78   |
| C.V. (%)     |                                        | 41.94 | 12.83  | 13.13  | 11.44    |

Remarks : Means followed by the same letter in a column are not significantly different (p > 0.05).

The result of ANOVA showed that the planting pattern as single factor only had significant effect (p<0.05) on maize height at 9 weeks after planting, meanwhile variety did not give significant effect on the age of 3 until 12 weeks after planting (Figure 1). At 9 weeks after planting, P2 maize height was higher (174.90 cm) compared to P1(168.43 cm) (Figure 1b). [31] stated that the height growth of maize in agroforestry pattern was significantly influenced by the existence of trees on 6 and 9 weeks after planting. Thus, photosynthesis effects which inhibited by the tree canopy on the late phase have more influence on the critical phase on maize yield compared to the early phase. The difference in height growth between P1 and P2 was also caused by the difference plant density. Higher population of maize on P2 made tight competition in capturing the sunlight, so the P2 grew taller than P1.

[32] explained that the high plant population can cause the emerge of competition in a clump of plant to get light so that the maize grow more in height. Beside between the maize plants itself, competition also happened between maize and the *ganitri* trees.
Figure 1. Maize growth development at 6 weeks after planting on: a) variety (V1: single cob, V2: double cobs) and b) different planting pattern (P1: two rows per alley, P2: three rows per alley)

Combination of variety and planting pattern gave significant result on 3 and 12 weeks after planting (Table 3). The highest growth can be found on V2P2 (89.83 cm, 172.79 cm, 178.75 cm and 187.71 cm), even though on 6 and 9 weeks after planting did not show any significant difference compared to other treatments. V1P2 was the shortest on 3 and 12 weeks after planting, meanwhile V1P1 had the shortest average height on 6 weeks after planting and V2P1 on 6 weeks after planting. Maize varieties responded the planting pattern differently. The result revealed that the growth of single cob variety was better on two rows on an alley, while the double cobs gained optimum result on three rows per alley. [16] stated that the genetic characteristics of maize has different sensibility and respond to spacing which reflected by the difference in the plant’s height.

Analysis of variance result showed that variety (V) had significant result on kernel’s weight, whilst planting pattern (P) had significant results on stover’s dry weight and kernel’s dry weight. Maize variety and planting pattern and also the combination of both, did not give significant effects on cob’s length and diameter, kernel’s dry weight and harvest index as shown in Table 4.
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Table 4. Maize morphology and production on variety and planting pattern treatment on ganitri based agroforestry

| Treatment | CL (cm) | CD (cm) | TDW (g/pl) | HI (#) | GY (t ha⁻¹) |
|-----------|---------|---------|------------|-------|-------------|
| Variety (V) :                                      |         |         |            |       |             |
| - V1 (Single cob)       | 14.64   | 3.09    | 202.33     | 0.48  | 2.26 b      |
| - V2 (Double cobs)      | 15.77   | 3.40    | 213.72     | 0.44  | 4.25 a      |
| Planting Pattern (P) : |         |         |            |       |             |
| - P1 (2 rows per alley) | 14.62   | 3.07    | 192.89 b   | 0.45  | 2.76 b      |
| - P2 (3 rows per alley) | 15.79   | 3.42    | 223.17 a   | 0.47  | 4.07 a      |
| Combination (V x P) : |         |         |            |       |             |
| - V1 x P1               | 14.21   | 2.81    | 203.00 b   | 0.48  | 2.13        |
| - V1 x P2               | 15.07   | 3.37    | 201.67 b   | 0.48  | 3.60        |
| - V2 x P1               | 15.02   | 3.33    | 182.78 b   | 0.43  | 2.76        |
| - V2 x P2               | 16.51   | 3.47    | 244.67 a   | 0.45  | 4.55        |
| Mean                    | 15.20   | 3.24    | 208.03     | 0.46  | 3.26        |
| C.V. (%)                | 13.56   | 16.14   | 18.96      | 20.03 | 26.05       |

Remark : CL = cob’s length, CD = cob’s diameter, TDW = total dry weight, GY = grain yield, HI = Harvest Index, Means followed by the same letter in a column are not significantly different (p > 0.05).

Insignificant differences on component respond of maize yield can be found on length, cob’s diameter and harvest index parameter (Table 4). Meanwhile, treatment combination between double cobs variety and three maize rows per alley (V2P2) produced the highest stover’s dry weight as much as 244.67 g/plant, while other treatments did not give any significant results. This matter matched with the result from [16] which showed that combination between variety and spacing have significant effects on stover’s dry weight. Double cobs maize variety (V2) gained higher production compared to single cob variety (V1) as much as 4.34 t ha⁻¹ kernel’s dry weight. Meanwhile, 3 rows of maize per alley (P2), produced higher kernel’s dry weight compared to 2 rows per alley (P1) as much as 4.07 t/ha. [16] mentioned that maize’s growth and productivity were affected significantly by the spacing and variety. Variety and spacing give significant effects on plant’s height, total leaf area, plant’s dry weight, and net assimilation rate. Though did not give any significant effects compared to other treatments, V2P2 gained highest result as much as 4.55 t/ha. [7] reported that the maize production on alternate rows with manglid tree (Magnolia champaca) gave production as much as 8.56 t/ha (hybrid maize) and 6.03 ton/ha (local breed) on 3 m x 3 m ganitri’s spacing. Wider tree-shade spacing gave bigger opportunity for maize to get more sunlight. Meanwhile, combination between maize-soya bean and manglid tree produced 1.22 t ha⁻¹ [33]. Maize planting used alley cropping pattern together with Gliricidia sepium produced 3.28 t ha⁻¹, Leucaena leucocephala 3.19 t ha⁻¹, Cajanus cajan 3.15 t ha⁻¹ and Senna siamea 3.10 t ha⁻¹ [17].

Generally, combination between double cobs maize with three rows per alley showed better growth and better yield compared to other planting pattern. Three rows planting pattern can increase the number of maizes per population which caused the high of production per unit area. However, the closer spacing of maize to ganitri tree, the maize plants can grow and produce well. [17] mentioned that the decline of crop yield on closer spacing with timber crop was more affected by the competition in gaining light, nutrition and water. The result of this research showed the low competition between maize and ganitri trees on 75 cm spacing. Moreover, the height growth of maize which faster than ganitri tree height
starting in 4 weeks after plating, made the maize can still absorb plenty of sunlight. Thus, created higher growth and yield of maize.

3.3. Ganitri Performance

Ganitri performance in agroforestry pattern combined with maize variety is showed in Table 4. Variety (V) and maize planting pattern (P) with the combination of both factors did not give any significant results on height growth and ganitri’s diameter on 5 months after planting. While, the branch number of ganitri tree was only affected by single factor (the maize planting pattern), the maize variety and interaction between V and P revealed insignificant results (Figure 2).

| Variety         | Planting Pattern (rows per alley) | Height (m) | Diameter (cm) | Branch number (≥) |
|-----------------|-----------------------------------|------------|---------------|------------------|
| Single cob (V1) | 2 rows (P1)                       | 0.41       | 0.42          | 8.26             |
|                 | 3 rows (P2)                       | 0.36       | 0.35          | 7.10             |
| Double cobs 2 (V2) | 2 rows (P1)               | 0.41       | 0.37          | 9.86             |
|                 | 3 rows (P2)                       | 0.39       | 0.36          | 6.93             |
| mean            |                                   | 0.39       | 0.37          | 8.04             |
| C.V. (%)        | 33.86                             | 44.51      | 37.88         |

Source: analysed data

The growth of ganitri on the early agroforestry which was planted in combination with different maize variety and planting pattern showed insignificantly different result. The average height of ganitri ranged between 0.39-0.41 m, diameter 0.35-0.42 cm and branch number 6.93-9.86 pieces (Table 5). Despite insignificant result, V1P1 gained highest growth rate and diameter. While, the highest branch number growth was gained by V2P1. Significant response was showed by the parameter of the number of branches on the different maize planting pattern (Figure 2a). Ganitri which planted with 2 rows of maize per ganitri’s alley (P2) had more branches compared to 3 rows of maize per ganitri’s alley. Likewise, the height growth and stem’s diameter of ganitri showed similar tendency even though it was not significant (Figure 2b). Former matter was caused by the higher maize density on 3 rows per alley and the spacing between maize and ganitri was closer than 2 rows per alley, so that the competition between components were higher. Based on [18], the increase on plant density can decrease the branch size, increase the lower branch mortality level, causing tilted branch, and decreasing stem’s diameter. [34] added that the dispersal of tree branch was commonly depending on the spacing.
Figure 2. The growth of stem’s height and diameter (a) with the branch number (b) ganitri with different maize’s planting pattern (P1: 2 rows per alley, P2: 3 rows per alley).

Figure 2 indicates that maize can become competitor on the early stage of ganitri-based agroforestry. The fast growth of maize caused the competition especially on sunlight capture. Started on 6 weeks after planting, the average height of maize had already taller than ganitri (data not shown). According to [18], on intercropping system, tree species recognized the maize plant as a competitor so the tree grows to avoid sunlight competition, even on the early stage of growth. Followed by [35] reported that maize has higher ability to compete compare to soya bean because it has higher stem and wider leaves crown. Maize is superior in absorbing water, nutrients, and light. Maize roots development can inhibit soya bean growth.

The occurrence of significant response of branch growth on different maize planting pattern gives both positive and negative implications correspond to the objective of ganitri cultivation. [8] reported that the two main objectives on ganitri cultivation by the community nowadays are the seeds and the timbers. The decreasing in the number of ganitri’s branch had positive influence, in the condition that the ganitri’s wood was intended to be sawn timber. Branching will affect the bole height, straightness, and wood quality. In contrary, if the objective was intended to produce fruit and seed, lower number of branches will decrease the fruit yield. Therefore, the result of this research can be used as consideration in applying agroforestry pattern, especially in the early agroforestry.

4. Conclusion
Micro climate characteristics which measured in the alleys between the tree rows included the light intensity, air temperature and relative air moisture are generally similar for all treatments. Interaction between variety and planting pattern had significant effects on the average height growth on the beginning and the end of the maize cultivation, but did not give different response to the early growth of ganitri, except in the parameter of the number of branches. The application of double cobs variety with 3 rows per alley gave the highest growth and yield, and also did not inhibit the growth of ganitri. This planting pattern is a potential pattern to be developed mainly in the first phase of agroforestry to increase the dry-land productivity.

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