The potential of turmeric (Curcuma xanthorrhiza) in agroforestry system based on silk tree (Albizia chinensis)

D Purnomo¹, M S Budiastuti¹, A T Sakya¹ and M I Cholid²
¹Study Program of Agrotechnology, Faculty of Agriculture, Universitas Sebelas Maret, Jl. Ir. Sutami 36A, Surakarta, Central of Java, Indonesia 57126
²Study Program of Agrotechnology, Faculty of Agriculture, Universitas Sebelas Maret, Jl. Ir. Sutami 36A, Surakarta, Central of Java, Indonesia 57126

Email: djpuruns@gmail.com

Abstract. Turmeric (Curcuma xanthorrhiza Roxb.) is a traditional medicinal plant. In Indonesia, it is generally cultivated in village home gardens. Farmers conducted very simple cultivation method of turmeric, without specific maintenance and below varies tree. The experiment was conducted by cultivating turmeric below silk trees in the agroforestry system. The experiment was arranged split plot design, the first factor was three level of irradiation (turmeric monoculture/full irradiation, turmeric below silk tree with pruning canopy, and turmeric below silk tree no pruning). The second factor was fertilizer NPK 15-15-15 with three levels of doses (100, 150, and 200 kg ha⁻¹). Cultivating turmeric in agroforestry system based on silk tree which were one year old and not yet needed pruning, application of NPK 15-15-15 fertilizer 100 kg ha⁻¹ was enough. The rhizome yield of turmeric 3 months age reaches 139 g per plant (fresh weight). Litter fall from a silk tree one year old in one year is 30 kg per tree per year.

1. Introduction
Traditionally the yard in rural Indonesia, turmeric (Curcuma xanthorrhiza Roxb.) is grown simply to produce rhizomes commonly used as a spice vegetable and traditional medicine. Turmeric contains protein, fat, and carbohydrates, respectively 6.3, 5.1, and 69.4%, as well as minerals and water of 3.5 and 13.1% [1]. The use of the ginger rhizome as a traditional medicine other than in Indonesia, also in China and India [2]. Until now the compounds on the stems and rhizome of turmeric has been identified as many as 235 kinds, most of them are phenolics and terpenoids. Curcuminoid or curcumin (diarylheptanoid) (especially accumulates in the rhizome) and essential oils (essential oils) are major bioactive ingredients. The essential oils of leaves and flowers are generally dominated by monoterpens while the root and rhizomes are dominant sesquiterpenes [3]. Positive correlations occur between fenolate contents and total antioxidant capacity in the turmeric species A. chinensis [4]. In Indonesia the original C. colon from Bogor (West Java) contains curcumin 2315 - 3059 mg g⁻¹[2].

The content of these compounds make turmeric useful to enhance the immune system, as an anti-inflammatory, oxidant, carcinogenic, mutagenic, coagulants, fertility, diabetic, bacterial, fungal, protozoa, viruses, fibrotic, venom, ulcers, and hypotensive and hipokholesteremik [1]. Turmeric then become raw material of beverages industry, cosmetics, and natural dyes [5, 6]. The need of turmeric for industry is quite big [7]. Turmeric including the top five among the 31 species of medicinal plants
for industry, medicine and herbs, even the two highest ranks as a base material for ‘jamu gendong’ (carried herbal medicine).

The areas of turmeric development in Indonesia are 13 provinces in North Sumatera, Java, Bali, Kalimantan and South Sulawesi Island. The increase of national turmeric production rate in 2010 to 2014 was 11% per year, and in 2015, the production of turmeric was 27,840 tons from the harvest area of 14,803 ha (1.88 tons ha⁻¹) [8], 2019 production is expected to reach 47,795 tons. The productivity is very low when compared with the turmeric in Bangladesh that can reach 16.77 tons ha⁻¹ [9]. The increase of turmeric productivity in Indonesia is very potential because in a production center, turmeric reaches 17.3 ton ha⁻¹ with curcumin 0.5-1.7%, it is possible to be increased to 25 ton ha⁻¹ with curcumin level of 2-4% [10].

The cause of productivity of turmeric in Indonesia is low: turmeric is not at all a priority crop [11] so that the level of cultivation is still simple (not intensive). Most farmers grow turmeric under trees such as mango, ‘rambutan’, jackfruit, ‘durian’, and bananas in the yard. In relation to the needs of Indonesian special plant extracts as a drug ingredient, especially turmeric and temulawak [12], the potential for production to meet the needs should be attempted. Increased turmeric production through intensification is potentials to be done, but an extensive increase in conventional farmland cause in competition with staple plant. One of the opportunities of planting location is in forest land or under yard or stands in agroforestry system. Silk tree (Paraserianthes falcataria L. or Albizia chinensis) is currently a potentially cultivable tree, both personal (farmer) and institutional such as forestry or plantation.

Cultivation of turmeric in silk tree based agroforestry system has the opportunity to practice environmentally and healthy cultivation (Good and Health Agriculture Practices). Silk tree includes legumes, thus the soil is healthy as it provides natural N nutrients. The silk tree grows relatively quickly, the short harvest time, the small leaf canopy thereby passing the light to the underlying plants, the leaves easily fall out [13] containing high N elements (low C / N) so easily decompose then maintain the physical properties of the soil. The condition is very suitable for medicinal plants such as tumeric. [7] stated that based on technical efficiency and high criterion economics, the turmeric cultivation can be done by low energy cultivation (Low External Input Sustainable Agriculture) using NPK fertilization of 200 kg ha⁻¹ (urea) and 100 kg ha⁻¹ (SP-36 and KCl).

This study attempted to reveal: the light escaped from the canopy of silk tree within 3x3 m, the increase of light escaped from the canopy of the tree when pruned by a third of the lower canopy, the growth of tumeric under the conditions of light, and the contribution of tree litter (especially leaf) to nutrient needs for the tumeric, especially nitrogen. The results of this study are expected to contribute to the development of agricultural science and organic technology cultivation of medicinal plants in the silk tree based agroforestry system.

2. Material and Methods

The research was a field trial on individual silk tree forest land in Bakalan Village, Karanganyar, Central Java (geographical position 07° 41 ‘42.1 ”LS and 110° 58’ 46.7” BT and 400 m elevation above sea level), from November 2016 to March 2017. Turmeric is planted between silk trees (10 months aged in agroforestry system, plant spacing of 3 x 3 m), plant spacing tumeric is 50 x 50 cm, the tip of tumeric is 75 cm from silk tree, the area of each plot Unit experiments 150 x 150 cm. The experimental design was split plot based Randomized Complete Block Design (between block 3 m).

The first factor is the intensity of light (full intensity, the light under the canopy of silk tress is not pruned, and 1/3 of the lower part head is prunned). While the second factor is NPK compound fertilizer 15-15-15 (dose 100, 150, and 200 kg ha⁻¹), so there were 9 treatment combinations, each repeated 3 times resulting in 27 experimental units (13.5 x 40.5 m in size). The data of the observation were analyzed using variance (F0.05 test), if different was followed by Duncan test 0.05. Total N content (Kjedhal method), P (Olsen method) and K available (NH4O Ac 1 N pH7 extraction method), organic material (Walkley & Black method), pH (Walkley & Black type pH meter) and C-Organic (Walkley & Black method), as well as C/N (Walkley & Black method) were analyzed before planting.
The tillage was done two weeks before planting using hoe as deep as layers (20 cm) then added the basic fertilizer (manure) 20 ton ha\(^{-1}\). The amount of litter silk trees observed within 3 months about polyphenol content, lignin, and cellulose, as well as quantity.

Planting material was the rhizome of turmeric cultivation in Central Research and Development of Medicinal Plants and Traditional Medicines (B2P2TOOT Tawangmangu). The rhizomes are first planted in polybag with a mixture of soil and manure (3:1, weight/weight). Small rhizomes (aged one day) is planted in the field by burying it into the planting hole, the rhizome is covered with soil, manually. Maintenance includes: irrigation using a bucket every 1 week based on soil conditions until the soil looks wet under the field capacity. Weed management was done manually every time weeds grow, various weeds include: Putri Malu (Mimosa pudica), Teki-teki (Cyperus rotundus), and Bandotan (Ageratum conyzoides). Fertilizer was given according to treatment in three stages that is when the plants are 1 week, 1 month and 2 months, each 1/3 dose. Fertilizer was immersed into the hole around the plant (4 holes were made).

The growth observation consisted of the plant height (measured from the base of the stem to the highest leaf shoot), the number of leaves, the number of shoots, and the leaf area (Gravimetric method). Leaf N analysis using Kjeldahl method on third leaf from above, as well as chlorophyll analysis using destruction and spectrophotometer method, as a solvent is 95% diethyl ether (colorimetric method). Harvesting is done when the plants were 12 weeks (3 months) by removing and taking the rhizomes, rhizomes were then washed and dried (weighed to produce fresh rhizome weight). The rhizomes were then subsequently cut into and put in the oven at 80 °C for 24 hours resulting in dry weights of the rhizomes. The observation of silk tree litter using a rectangular plot of 1x1 m was placed under a tree canopy for 3 months (November-January), then weighed.

3. Results and discussion

3.1. Silk Tree, Micro Climate, and Soil

High silk tree at the age of 1 year 2 months about 4.5 m, canopy width ± 1.5 m, so tree with a distance of 3x3 m is still have a free shade space. The light escapes from the canopy of 27%, 8440 lux from 31200 lux (light in the open space), pruning tree canopy of the lower third of the canopy increases the light passes to 47% (14550 lux). The intensity of light is related to temperature and humidity. Temperatures under the canopy were not pruned during the morning, day and afternoon on average by 30.1°C, and increased to 32.5°C on the pruned canopies. Silk tree produced litter (leaves and twigs) 6.1 kg per tree, for 3 months (rainy season), so it was assumed to produce litter of about 30 kg per tree each year (in dry season litter is assumed to increase by one third).

The litter content of N-total, C-organic, and organic matter were 3.73, 33.92 and 57.67%, respectively, so that the potency of litter as source of N, C-organic, and organic matter was 113.76, 1034.56, and 1759.93 g per tree per year (1,264.6, 11,495.11, and 19,543.7 g per ha). Contribution of the year-old silk tree to soil fertility improvement was not yet apparent, soil analysis at the beginning of the experiments of N, P, and K content were 0.15% (low), 14.39 ppm (medium) and 0.16% (low). Some of the possible reasons why it happens are: the initial growth of silk tree was still fresh, nutrients are used by weed, or eroded.

3.2. Growth of Turmeric

3.2.1. Plant height, number of leaves, and number of tillers There was an interaction between light intensity and fertilizer dose at plant height responses of turmeric at 12 weeks (3 months). At full light, plant height of turmeric was highest in NPK 15-15-15 fertilization with doses of 100 kg ha\(^{-1}\), however at lower light intensity (silk tree pruned 1/3 of the lower canopy) has a higher plant and the highest plant was in application 150 kg ha\(^{-1}\) fertilizer. Turmeric under the canopy of silk tree was not pruned, the plant was higher (reach 145.3 cm) also on the crop fertilized 150 kg ha\(^{-1}\). Plants contain auxin, a plant regulators, on the tip (root and shoot) promote the enlargement and elongation of the cell.
Auksin is more active when light intensity is lower [14,15] making plants taller. At high light, high temperatures become high. When light is high, soil temperature becomes high resulting in increased activity of soil microorganisms. Such activity requires nutrient especially N so competition between plants with soil microorganism occurs. The competition is reduced when the soil temperature is low and the light areas are lower, so the plants are higher at higher fertilizer doses.

The number of leaves ranged from 9.2 to 10.57 strands, was not significantly different between light variation and fertilization. Plant height is related to the number of leaves as the leaves grow from the node stems. The internodes of the stem become wider if the plant is etiolated so that the number of nodes is lower. The number of leaves is almost the same both in higher plants (due to low light intensity) or lower plants, means the plants not yet experiencing etiolation so there has been no growth disorder.

Turmeric planted from tubers that have more than one bud so that form clump. The bud grows first as the parent plant while the other shoots as saplings. Leaves growing on the parent plant and also from the the saplings. The number of saplings on all three light treatment was three, meaning that the disorders growth because of low light intensity has not occurred

3.2.2. Leaf area index, biomass and tuber weight Leaves as light harvesters play the main role of photosynthetic organ. One of the leaf characters reflecting the potential of light absorption is the area of the leaf expressed in the leaf area index (LAI: the area of a leaf canopy of a plant per unit ground area where the plant grows). Turmeric under silk tree stands having higher LAI (1.09-1.36 than 0.99) indicates that the leaf was wider when the plant receives a lower light intensity. Plants are grown with wider distances, LAI is also lower [16]. Leaf area index of about one means intercepting light about 50% [17], it happens because the turmeric is cultivated under silk tree stands.

The process of photosynthesis by the leaves produces photosyntate, most of which accumulates in the vegetative part expressed in plant biomass. The biomass is then divided into: as deposits, metabolism, and translocation to the sink [18] The turmeric biomass at the age of 3 months reaches 59.19 (under full light) and about 70 g per plant under silk tree stands. This means that the turmeric was subjected to photosynthesis when the light is full. Turmeric is a C3 plant, when full light can decrease in photosynthesis rate due to photorespiration process.

Photosyntate in biomass then undergoes remobilization to the bottom, in this case the rhizomes, then used by humans (harvest). Quantitatively the harvest in the form of rhizomes is expressed in the rhizomes weight. The weight of the fresh rhizome (at harvest, aged of three months) about 139 g (under stand) and 129 g (full light). Low rhizome weight due to young harvest, turmeric is generally harvested at the age of 12 months and the rhizome reaches 380 g per plant [10]. The yield of rhizomes under stands higher than under full light indicates that photorespiration does occur means that turmeric plant is an adaptive plant to low light intensity.

4. Conclusions
The following conclusions were obtained from the research results:
1. Turmeric is cultivated in agroforestry system based on one year-old silk tree grow well, biomass and yield higher than full light (139 compared to 129 g of wet rhizome per plant).
2. Silk tree age of year as base agroforestry system does not need pruning.
3. Pruning a third of the lower canopy can be done as nutrient substitution especially N.
4. Silk tree produces litter as much as 30 kg per tree per year.

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