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Potential of Corn as Forage on Alfisol and Vertisol Soil in Agrosilvopastural System with *Kayuputih* (*Melaleuca leucadendron* Linn)

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Abstract

This research was aimed to know the morphologic and physiologic characteristics and corn plant production as forage on alfisol and vertisol soil at *Kayuputih* intercropping system. Supporting forage supply is one of goals in forest for food/feed program, and it significantly showed at *Kayuputih* (*Melaleuca leucadendron* Linn) intercropping system. *Kayuputih* intercropping system of corn was planted particularly at the 3rd rotation (May-July). The research performed by a strip plot design, soil type was the main plot, and the interface zone (IZ) was the secondary plot. Interface zone was 1 m (IZ-1), 2 m (IZ-2), and 3 m (IZ-3) distance from the *Kayuputih* plantation row. Growth and physiologic data was analyzed using Bartlette to obtain data homogenity, followed by analysis of variance and DMRT at 5% degree of confidence, data transformation was performed when needed. Contrast orthogonal (5%) test was used to do the grouping based on soil type. Biplot technique as a development from the multivariate technique was performed to determine the stability of IZ treatment toward result. Forage potency on alfisol was higher (5.04 ton/ha) than on vertisol (4.04 ton/ha). Interaction between the IZ and soil type was found at several variables: number of stomata, stomatal aperture width, proline content, plant growth rate on 3-6 wap, net assimilation rate on 3-6 wap, fresh root weight on 3 wap, root dry weight on 3 wap, fresh canopy weight on 6 wap and canopy dry weight on 6 wap. The highest level of corn forage production was IZ-3 on alfisol soil (1.26 ton/ha) and the lowest production was IZ-1 on vertisol soil (0.73 ton/ha).

Keywords: *Kayuputih*, agrosilvopastural, alfisol, vertisol, corn, productivity

1. Introduction

Livestock development in tropical country like Indonesia facing continuous feed stock especially forages (quality and quantity), abundant in wet season but lack in dry season (Utomo, 2003). Meanwhile, not every farmer has their own land to be planted with grasses, so that agrosilvopastural become an alternative ways of land utilization to get both food and feed. Agrosilvopastural is one of the agroforestry techniques for integrating trees and crops in the same space and time. Agroforestry is a land-use system that combines woody plants with non woody plants forming ecological and economic interactions between woody plants with other components (Huxley, 1999); conserve soil quality, improve farmer income, and reduce risk farming failure (Suwignyo et al., 2006). Intercropping *Kayuputih* is one of the forestry program to involve communities in forest management.

Kayuputih intercropping system has longer execution time compare with other forests (teak, pine, acacia, etc.). The effect of shade in *Kayuputih* intercropping is very minimal, due to periodic coppiced system of *Kayuputih*. Thus, cultivation of crops can be done continuously. Time duration of *Kayuputih* intercropping production, which can take place until the end of the cycle, is about 30 years. This is different from non-*Kayuputih*, active intercropping only takes place at the early stage of woody plants.

Intercropping time that goes on continuously in the *Kayuputih* forests including *coincident* category is a combination of trees and crops during the period of cultivation of agroforestry. This is in contrast with other categories Nair (1993) stated that intercropping including the type of *concomitant* in the combination at the beginning or end of time cultivating a type/components of agroforestry.

Corn became a common commodity in the *Kayuputih* intercropping system because it occupies the first and third rotation. The first rotation is focused on the goal of planting corn grain yield, while the third rotation designation as forage. Corn is a grain crops of the grass family that has high economic value, in addition to young corn as a source of vegetable and carbohydrate. While, by-products of corn such as leaves, cobs, corn husk and bran can be used as a component of animal feed either directly or after a processing (Umiyasih & Vienna, 2008). The crude protein content of corn is about 10%, crude fat 4%, and carbohydrate 61% (Martin, 1975 in Supaman, 2003). Corn straw is the stem and leaves of corn that had been left to dry in the fields and harvested when corn cobs picked (Mariyono et al., 2004). Corn husks are the outer skin of corn fruit that has fairly high sugar content (Anggraeny et al., 2005, 2006). This study aimed to determine the morphological characteristics, physiological and production of forage corn plant as animal feed on the alfisol and vertisol soil in intercropping system of *Kayuputih*.

2. Materials and Method

This study was administratively located in Bleberan, Playen, Gunungkidul district, Central Java, Indonesia. The forest area included in the Menggoran Forest Resort (RPH Menggoran), Playen Forest Section (BDH Playen), Yogyakarta Foret Management District (KPH Yogyakarta). Intercropping corn in the *Kayuputih* was devoted in the third rotation (May-July). The first rotation in the rainy season (November-February), the second rotation (March-May) and the third namely "*bera*" (waiting until the next rainy season).

The study was conducted in May-July 2014 with a multilane plot design (strip plots). The main plot is the type of soil that consists of alfisol and vertisol soil. Subplots are interface. There are 3 interface zone (IZ) which consists of IZ-1 (1 meter from row/line of *Kayuputih*), IZ-2 (2 meters from the line of *Kayuputih*) and IZ-3 (3 meters from the line of *Kayuputih*). There were 6 combinations with 4 replications each.

The content of proline was observed by determining perfect leaf growth and the youngest by the method of Bates (Arora and Saradhi, 1995). Proline levels were determined by the equation:

$$\text{Proline content} = \text{proline content (mg cm}^{-3}) \times 0{,}347 \text{ mol g}^{-1} \tag{1}$$

Proline content was converted into proline content per plant by multiplying proline level with the plant dry weight.

Chlorophyll content was determined according Harbourne (1987) and Gross (1991). Chlorophyll level was counted with the following formula:

$$a \text{ chlorophyll: } -0{,}00269 \times \lambda 645 + 0{,}00127 \times \lambda 663 \tag{2}$$

$$b \text{ chlorophyll: } 0{,}0229 \times \lambda 645 - 0{,}00468 \times \lambda 663 \tag{3}$$

$$\text{Total chlorophyll: } 0{,}0202 \times \lambda 645 + 0{,}00802 \times \lambda 663 \tag{4}$$

Observations nitrate reductase activity (NRA) carried out by a modified method Hageman and Hucklesby (Hartiko, 1983). Nitrate reductase activity can be determined by the formula:

Observation of the nitrate reductase activity was done with Hageman and Hucklesby modified method (Hartiko 1983). The nitrate reductase activity (NRA) was with the formula:

$$NRA = \frac{sampel\ absorbance}{standard\ absorbance} \times \frac{100}{leaf\ \ fresh\, weight} \times \frac{1}{incubation\ period} \times \frac{50}{100} \tag{5}$$

Observation of CO_2 content of leaf cell and photosynthetic rate was done with photosynthetic Analyzer type LI Cor LI 6400.

Site stratification was based on a map of rainfall, slope and soil type with a scale of 1:25000. Map of rainfall, slope and soil type then made into the land mapping unit (LMU) with map overlay technique so that there are 7 LMU. Analysis of stands of *Kayuputih* was done with the calculation of density and basal area on each LMU.

Data of growth and physiological components were analyzed with Bartlette test first to determine the homogeneity of the data. Homogened data continued analysis of variance (ANOVA) and DMRT (5%). Transformation of data must be in advance if the data heterogen. Orthogonal contrast test was done to classify the level of 5% based on the type of soil. Stability treatment interface zone of the results in any environment do Biplot technique which is the development of multivariate techniques.

3. Results

The type of soil showed that alfisol soil types have significant better value compared withvertisol soil (Table 1).

Table 1. Leaf area (cm^2) and greenish leaves of the various zones and soil types

Treatment	Leaf Area		Greenish leaves	
	3 wap	6 wap	3 wap	6 wap
Interface zone				
IZ-1	893.35 b	6627.75 c	35.64 c	42.77 c
IZ-2	1050.83 a	7045.55 b	36.06 b	43.27 b
IZ-3	1055.20 a	7305.80 a	36.32 a	43.59 a
Soil type				
Alfisol	1044.87 a	7501.90 a	37.46 a	44.95 a
Vertisol	954.72 b	6484.17 b	34.55 b	41.46 b
Average	999.79	6993.03	36.01	43.21
Interaction	-	-	-	-

Note. The number followed by the letter is the same in comparison groups in each column showing insignificant difference in orthogonal contrast of 5%.

Based on the results of variance showed, there was no interaction between interface zones with the type of soil on corn crops in *Kayuputih* intercropping system. IZ-3 was showed the best leaf area and leaf greenish followed by IZ-2 and IZ-1. This is allegedly due to underground sources of competition space grows roots, moisture content and nutrients between corn with *Kayuputih* will give significant effect on corn. Sources on the ground, the sun light was not significantly affect due to the form of *Kayuputih* canopy grows vertically and does not overshadow the corn crop because coppiced every year.

Interface zone with the type of soil on root length and height parameters of corn plants showed no interaction. Interface zone-3 mostly showed the best value. In the type of soil, alfisol soil showed significantly higher value than the vertisol soil (Table 2).

Table 2. The root length (m) and plant height (cm) in various zones and soil types

Treatment	Root length		High	
	3 wap	6 wap	3 wap	6 wap
Interface zone				
IZ-1	0.026 b	1.51 c	33.18 b	80.55 a
IZ-2	0.029 a	1.63 b	41.76 ab	97.88 a
IZ-3	0.030 a	1.68 a	46.80 a	100.78 a
Soil type				
Alfisol	0.030 a	1.65 a	44.15 a	99.38 a
Vertisol	0.027 b	1.56 b	37.01 b	86.75 b
Average	0.03	1.61	40.58	93.07
Interaction	-	-	-	-

Note. The number followed by the letter is the same in comparison groups in each column showing insignificant difference in orthogonal contrast of 5%.

High and low greenish and leaf area will affect to the formation of photosynthate by corn plants. It will be positively correlated with root length and height of corn. Special for root length parameters, describe the competition of growth roots area between corn and *Kayuputih*, aside competition of nutrients and water. Alfisol soil resulted a longer roots because of the structure of alfisol soil in the dry season more crumbs than vertisol soil.

Based on the results of variance showed that there was an interaction between the IZ with the type of soil on the number of stomata, stomatal aperture width, the content of proline, crop growth rate (CGR) and net assimilation rate (NAR) (Table 3).

Table 3. Number of stomata (dm^{-2} leaf), stomatal aperture width (µm), proline content (µg/g), CGR 3-6 (g/cm^2/week) and NAR 3-6 (g/cm^2/week) in various zones and soil types

Treatment		Number of Stomata	Stomatal aperture width	The content of proline	CGR 3-6	NAR 3-6
Alfisol	IZ-1	23.78 c	1.57 e	4.08 d	0.0053 d	0.0029 c
	IZ-2	24.19 b	2.39 b	3.90 d	0.0062 b	0.0034 b
	IZ-3	25.13 a	3.54 a	3.33 e	0.0067 a	0.0035 ab
Vertisol	IZ-1	22.44 d	1.08 f	5.17 a	0.0039 e	0.0025 d
	IZ-2	23.83 c	1.89 d	4.76 b	0.0058 c	0.0036 a
	IZ-3	24.07 bc	2.13 c	4.28 c	0.0059 bc	0.0034 b
Average		23.91	2.10	4.25	0.0056	0.0032
Interaction		+	+	+	+	+

Note. The number followed by the letter is the same in comparison groups in each column showing insignificant difference in orthogonal contrast of 5%.

Based on the analysis of variance showed there was no interaction between the IZ with the type of soil on the 6 wap fresh weight (FW) and root dry weight (DW) parameters, also 3 wap fresh weight and dry canopy. Interface zone-3 showed the highest value compared to other zones, whereas alfisol soil showed significantly higher compared with vertisol soil (Table 4).

Table 4. The fresh root weight (g), root dry weight (g), fresh weight and canopy dry weight (g) in the various zones and soil types

Treatment	FW Root	DW Root	FW Canopy	DW Canopy
	6 wap	6 wap	3 wap	3 wap
Interface zone				
IZ-1	41.77 b	8.12 b	24.23 c	4.28 c
IZ-2	56.25 a	10.93 a	32.06 b	5.66 b
IZ-3	62.32 a	12.11 a	38.07 a	6.72 a
Soil type				
Alfisol	59.65 a	11.59 a	35.50 a	6.27 a
Vertisol	47.24 b	9.18 b	27.40 b	4.84 b
Average	53.45	10.39	31.45	5.55
Interaction	-	-	-	-

Note. Figures followed by the same letter in the same row and column are not significantly different by DMRT 5%. Sign (-) indicates no interaction.

Table 5. Roots fresh weight (g), root dry weight (g), canopy fresh weight and dry weight (g) in the various zones and soil types

Treatment		FW Root	DW Root	FW Canopy	DW Canopy
		3 wap	3 wap	6 wap	6 wap
Alfisol	IZ-1	4.44 d	0.95 d	114.67 c	23.73 d
	IZ-2	7.50 b	1.60 b	125.94 b	28.71 b
	IZ-3	9.99 a	2.13 a	137.74 a	31.40 a
Vertisol	IZ-1	3.71 e	0.79 e	79.75 e	18.18 e
	IZ-2	4.77 d	1.02 c	104.10 d	26.14 c
	IZ-3	5.73 c	1.22 c	119.14 c	27.16 c
Average		6.02	1.29	113.56	25.89
Interaction		+	+	+	+

Note. The number followed by the letter is the same in comparison groups in each column showing insignificant difference in orthogonal contrast of 5%.

Table 6. Fresh weight (ton/ha) and dry weight (ton/ha) in various zones and soil types

Treatment		FW	DW
Alfisol	IZ-1	4.59 c	0.95 c
	IZ-2	5.04 b	1.15 b
	IZ-3	5.51 a	1.26 a
Vertisol	IZ-1	3.19 e	0.73 e
	IZ-2	4.16 d	1.05 d
	IZ-3	4.77 c	1.09 c
Average		4.54	1.04
Soil type $^{*)}$			
Alfisol		5.04 a	1.12 a
Vertisol		4.04 b	0.95 b
Average		4.54	1.04

Note. The number followed by the letter is the same in comparison groups in each column showing insignificant difference in orthogonal contrast of 5%.

Based on the biplot results which was the development of multivariate techniques showed that IZ-3 fits on alfisol and vertisol soil types. While, IZ-2 and IZ-1 shows the unstable results on alfisol and vertisol soil types (Figure 1).

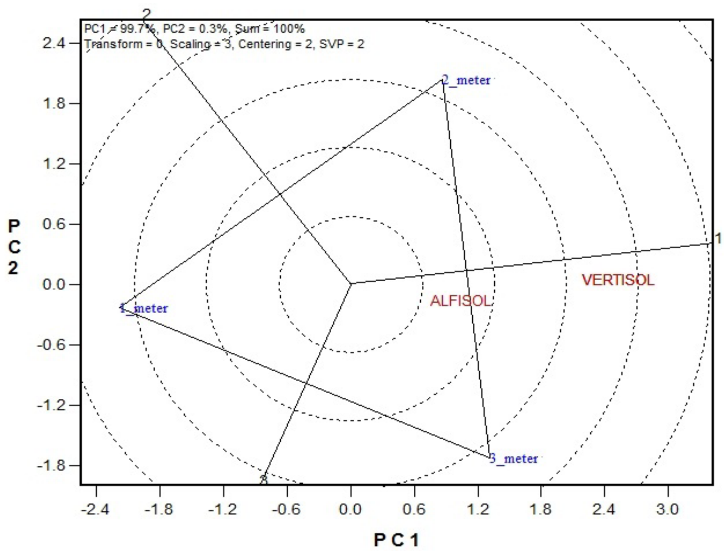

Figure 1. Multivariate analysis biplot interface zone and the type of soil

Kayuputih plantation in RPH Menggoran showed abnormalities of plantation, indicated with the number of *Kayuputih* trees per hectare was below standard of KPH Yogyakarta (2,500 trees/ha). The highest density values of *Kayuputih* was at site map unit (LMU) 3 (2,492 trees/ha). The lowest density values of *Kayuputih* was in the LMU 6 (317 trees/ha). LMU 3 has the highest potential of basal area compared with other LMU that is 29,271 m^2/ha. Meanwhile, the smallest value of basal area was at LMU 2 which reaches 0.771 m^2/ha (Table 7).

Table 7. Conditions of *Kayuputih* plantation in RPH Menggoran

LMU	Compartment	Soil type	Slope (%)	Rainfall (mm/year)	Area (Ha)	Trees Density	Basal area(m^2/ha)
1	81	Vertisol	15-25	<1750	34	923	8.089
2	81	Alfisol	15-25	2000	40	328	0.771
3	81	Vertisol	8-15	<1750	44	2,492	29.271
4	82	Vertisol	8-15	<1750	99	1,665	12.197
5	83	Vertisol	15-25	<1750	25	1,513	13.254
6	84	Vertisol	15-25	<1750	19	317	3.426
7	87	Alfisol	15-25	2000	58	751	4.195

4. Discussion

Competition underground sources might be caused by competition of nutrients, especially nitrogen (N) and magnesium (Mg), which are both associated with the formation of leaf chlorophyll. The high and low of chlorophyll value can be expressed with high greenish that ultimately effect on leaf area. Alfisol soil types showed that leaf greenish values was significantly higher than vertisol, it may be caused by nutrients and soil moisture in the alfisol soil was higher compared with vertisol soil types. In the dry season, nutrients in the vertisol soil will more difficult be absorbed by plants due to strongly bound by clay mineral types of 2:1.

Mukanda and Mapiki (2001) stated that problem of clay vertisol soil types is physical properties of heavy clay soil texture, nature expands and shrinks, low infiltration rate, and slow water drainage. Sloping terrain will accelerate the loss of water so that the soil becomes better drainage. Bad drainage will cause the water in the soil surface is difficult to infiltrate into the ground, causing the plant has the potential inhibition of diffusion of O_2 and leaching of nutrients.

Stomata has an important role in the process of plants photosynthesis. According to Kramer and Boyer (1995) an important role in the process of plants photosynthesis such as the diffusion of CO_2, control the rate of transpiration through the stomata opening and closing mechanism. Stomatal consists of guard cells and cover cells that surrounded by neighbor cells (Fahn, 1992).

Interface zone-3 in alfisol soil showed the best value because on that zone, underground competition was relatively the lowest and alfisol soil provide more nutrients and water compared with vertisol soil (Table 3). Density and stomatal aperture width indicates the shape of plant adaptation to the environment. The stomata will open wide when adequate soil moisture and will close when the shortage of moisture.

The difference in stomatal aperture width above is strengthens that was occurs a competition of nutrient in various zones and two types of soil. This was confirmed by the proline content that synthesized by plant. Plants that emit a lot of proline indicated the lack of water, so that plants need to synthesize proline to adapt to the environment. Interface zone-1 located on vertisol soil showed the highest levels of proline. This means that competition of moisture in the soil type and that zone was the highest compared to the other combinations.

Kishore et al. (2005) stated that proline in plants will increase due to increasing synthesis and decreasing its degradation in plants with water stress condition. The decline of water content will cause the plant induce proline to maintain cell turgor pressure (Round et al., 2000). Matsuo et al. (1995) stated that increasing soluble material such as proline at low soil moisture status in an attempt to osmotic adjustment to maintain metabolic process well continues.

Proline is the result of plant secondary metabolites, produced when plant in the stress environment, especially water. Hare and Cress (1997) stated that proline is osmolit for osmotic adjustment, stabilize the sub-cellular structures, neutralizing free radicals and cellular redox buffer in plants that cannot stand with environmental stresses.

Based on the results of variance indicated that there was interaction between interface zone with the types of soil in the 3 wap fresh root weight parameters, 3 wap dry root weight, 6 mst canopy fresh weight and canopy dry weight. Interface zone-3 that was at the alfisol soil showed the significant highest value in all parameters, while the IZ-1 which was at vertisol soil showed the lowest value.

Fresh weight and dry weight of both roots and canopy showed the pile photosynthate produced by the plant. The process of increasing the weight of the plants come from the metabolism and physiological aspects of plant. From the physiological aspect showed the lowest competition present in the IZ-3 and alfisol soil types. Physiological aspects will affect the weight of the plant. The weight of the plants was positively correlated with leaf area, root length, leaf greenish and stomatal morphology.

Increasing forage production was done with the principle of minimizing the chance of damage to *Kayuputih* plantation. Manipulate the cropping pattern was one way that can be done. Corn is generally planted with a range of 70 × 30 cm or 70 × 25 cm with two seeds per hole. Corn planted in 3rd rotation in *Kayuputih* intercropping system can be set in higher density (closer range of hole). The higher density was purposed to have double scenario, corn plant harvested as forage if lack of water or left it some to produce seed if enough water. Basuki (2000) stated that the corn crop for feed purpose can be planted more densely spaced at 50 × 20 cm with two seeds per hole. Planting of corn with higher density per ha is expected the increasing of forage production.

Another strategy that can be done is to improve the quality or stock of feed, feed the animal in the post-harvest processing instead of fresh forage. Corn plants grown in alfisol soil produce fresh corn biomass at 5.40 ton/ha. Corn plants grown in vertisol soil produce fresh corn biomass of 4.04 ton/ha. The potential by product of corn for animal feed in Indonesia is very huge, but was not maximized yet (Retnani et al., 2005). This was due to rapid deterioration corn by product after harvest, bulky, and seasonal. One of forage processing technology is silage. Making of silage has the same principle with the manufacture of traditional foods so easily understood by farmers (Mould et al., 2005).

Another by product process (corn straw, rice straw) is fermentation. Feed fermentation can improve the digestibility so that the increase in body weight of cattle to be faster (Suwignyo et al., 2010). Ration formulation using forage as the main ingredient, and then fitted with a supplement, the addition of additives such as probiotics and enzymes synthesis boosters such as pro-vitamin will ensure adequate nutrition for livestock (Erowati, 2000; Mullik & Permana, 2009). Another advantage obtained by the loss of anti-nutrients substances that can cause poisoning of livestock (Salazar & Jaker, 2001; Winugroho et al., 2009; Elevitch & Thomson, 2006).

Treatment of corn crop by product is done to increase the shelf life and nutritional value (Ummiyasih and Vienna, 2008). The nutritional value of corn silage 30% to 50% higher than the fresh corn plants and 10 times more efficient storage compared with hay (William et al., 2013). Fermented corn crop by product is also very rich in several essential minerals and low anti-nutrients content (Oseni et al., 2007). Thus, the feed derived from corn plants may replace grasses and legumes that are more expensive (Koster, 2013).

Potential forage in IZ-3 on alfisol soil types showed the highest value compared to other combinations (5.51 ton/ha fresh forage and 1.26 ton/ha dry forage), while IZ-1 on vertisol soil showed the lowest value (3.19 ton/ha fresh forage and 0.73 ton/ha dry forage) (Table 6).

Potential forage at RPH Menggoran on alfisol soil showed significantly higher value than the vertisol soil. Alfisol soil produces fresh corn plant biomass 5.40 ton/ha with dry weight 1.12 ton/ha, while in the vertisol soil produces fresh corn plant biomass 4.04 ton/ha with dry weight 0.95 ton/ha.

From our results, there was an interaction between IZ with the type of soil on a variable: number of stomata, stomatal aperture width, the proline content, plant growth rate on 3-6 wap, net assimilation rate on 3-6 wap, root fresh weight on 3 wap, root dry weight on 3 wap, canopy fresh weight on 6 wap and canopy dry weight on 6 wap. The highest level of corn production was in IZ-3 on alfisol soil (1.26 ton/ha), while in IZ-1 on vertisol soil was the lowest production (0.73 ton/ha). Potential fresh forage for livestock on alfisol soil showed higher values (5.04 ton/ha) compared to the vertisol soil (4.04 ton/ha).

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