Nutrient Deficiency Induces Branch and Shoot Dieback in Robusta Coffee

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Nutrient Deficiency Induces Branch and Shoot Dieback in Robusta Coffee

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Abstract. In southern Sumatra, Robusta coffee is grown mainly in mountain regions, undulating and steep lands, and marginal soils. Management of soil nutrients is a key issue to maintain sustainable coffee production. This survey was conducted at the field of Farmer Training Center (FTC), at Pulau Panggung Village, Semendo Darat Laut Sub-district, Muara Enim District of South Sumatra Province, Indonesia. The trees of seven coffee clones were randomly sampled. The soil of 0-20 cm depth and full-grown leaves from middle branches was compositely sampled. The results of soil analysis and visual symptoms showed a deficiency of macro nutrient including N, P, K, and Mg that coincident with a high incidence of dieback symptoms. We observed that branch dieback incidence was 62-100% with severity score 1.0-2.5 and shoots dieback incidence was 15-50% with severity score 1.0-3.0. Local coffee clone showed a better tolerance on branch and shoots dieback and higher yield potential based on number of fruits and pinhead fruit per bunch. The results of observation on leaf symptoms of nutrient deficiency, slow plant growth, dieback incidence, plant death, and low plant population showed as a failure of coffee establishment induced by low soil fertility and poor plant management.

1. Introduction

Southern Sumatra including Province of Lampung, South Sumatra, and Bengkulu is the main producer of Robusta coffee in Indonesia. In 2019, It produced 364,835 ton coffee bean which shared for 47.9% of Indonesia coffee production [1]. In the region, Robusta coffee is grown mainly in mountain regions, undulating, steep lands, and marginal soils. In addition, high intensity of rainfall resulted in high soil erosion particularly at fields under monoculture coffee and clean weeding [2]. Coffee agroforestry systems are supposed to be biodynamic systems that reduce soil erosion [3], enhance microbial activity and maintain soil nutrient and organic carbon [4].

Statistic data in the period 2011-2018 showed that the coffee yield of smallholders in Indonesia was only 743 kg/ha [1]. Management of soil nutrients is a key issue to increase coffee yield and to maintain sustainable coffee production. Low rate of fertilizer application is among the main constrain of coffee farming in Southern Sumatra. The rate of fertilizer was 58-75 kg N, 10-17 kg P_2O_5, and 10-16 kg K_2O which was far below the recommendation rate of 135 kg N, 35 kg P_2O_5 and 145 kg K_2O per ha [5].

Coffee is characterized by biennial yield that cause high variability of yield that induced by weather conditions and low rate of fertilization. In good season, coffee trees produce high yield and over bearing, then followed by low yield seasons. Farmers cope the yield variability as impact of season and climate change by applying the proper rate of fertilization [6]. However, farmers commonly applied only 100-200 kg ha of Urea and Phonska (NPK) that resulting in high yield variability [7].

Following over bearing, coffee dieback is mainly caused by poor nutrient supply especially for the non-shaded coffee fields after a long drought season. Coffee plants need a high dosage of nitrogen and potassium. Nitrogen supply is important for leaves and flower buds to grow and for carbohydrate production that is needed for fruits development. Whereas potassium is important in plant physiology

for growth and coffee berries development. Insufficient nutrient availability might cause empty berries and branches dieback [8]. Physiology and symptoms of deficiency of soil nutrients in coffee was been discussed in many reports including Flores et al [9] and Snoeck and Lambort [10].

When shoot dieback with high severity has occurred, the death of branches begins from the top and progresses downward. It is a complex phenomenon of plant physiology such as nutrient starvation and environmental stresses [11]. Over bearing or heavy bearing is phenomenon that drives leaf growth and leaf retention, pattern of biennial bearing, and branches dieback of coffee plant [12].

2. Methods

This study was conducted using survey method by observing the existing coffee farm at Semendo Farmer Training Center (FTC) and farmers' farm at Pulau Panggung Village, Semendo Darat Laut Sub-district, Muara Enim District of South Sumatra Province, Indonesia. The village situated at 4°04'09"S 103°39'05E until 4°07'38"S 103°36'05"E, with altitude 650-900 m above sea level. We observed 7 plots of coffee clones including BP 358, SA 237, BP 409, BP 436, BP 534, BP 536, and local clone. Coffee trees were managed under low population of shade tree of *Leucaena leucocephala* and local recommendation of maintenance.

Mature coffee trees were sampled randomly in 3 rows with total 75 sampled trees from clones mentioned above. Observation was conducted to collect data of growth of fruiting trees, symptom nutrients deficiency and plant dieback. Soil of 0-20 cm depth and full-grown leaves from middle branches was composite sampled. Leaves deficiency symptoms was determined according to Flores et al [9]. We discriminated shoot dieback as symptoms of dying on the top branches which was not yet fruiting (known as B0 branches), while branch dieback as symptoms of dying on lateral (fruiting) branches (known as B1 and B2 branches). Dieback incidence was obtained as percentage of dieback per number of plants observed. Dieback severity was determined by average value of scores [13,14]. The scores for shoot dieback were: 1 = shoot growth retarded, leaves yellowing, no flush, 2 = some branches started to die, leaves were falling, 3 = all top branches were died. The scores for branch dieback were: 1 = lateral branch growth retarded, leaves yellowing, 2 = some lateral and fruiting branches started to die, leaves were falling, 3 = most lateral branches were died.

3. Results and Discussion

3.1. Growth and Potential Yield

Table 1 showed the performance of branch growth and fruiting among the coffee clones. Based on the mean and standard deviation, there was no significant difference among the clones on number of primary branches, number of primary branch fruiting, number of bunches per primary branch, and number of fruits per bunch. The six clones planted at FTC did not show better performance on branch growth and fruiting than local clones. Moreover, local clone showed better number of fruits and pinhead fruit per bunch. Region of Basemah was rich of superior local clones of Robusta coffee as reported by Syafaruddin et al [15] and Syafaruddin et al [16] including clones of Basemah 1, Basemah 2, Basemah 3, and Basemah 4 which has been released as national superior clones. Other farmers planted clone of Garudag which has high potential yield 0f 1.95 ton ha^{-1} with number of bunch/ branch 12.1 and number of fruits per bunch 23.8 [17].

Table 1. Growth and yield potential

Clone	PrimBr ± SD	PBrFruit ± SD	SBrFruit ± SD	Bch/PBr ± SD	Fruit/Bch ± SD	Pin/Bch ± SD
BP 358	36.5 ± 11.7	21.9 ± 8.2	8.9 ± 4.6	11.4 ± 3.1	11.7 ± 4.9	15.6 ± 6.9
SA237	38.2 ± 10.9	15.8 ± 6.9	4.3 ± 3.8	9.3 ± 2.8	11.4 ± 3.9	12.5 ± 4.6
BP 409	37.7 ± 14.8	14.8 ± 6.2	5.8 ± 5.1	10.2 ± 4.9	9.4 ± 3.3	16.4 ± 5.9
BP 436	32.3 ± 11.9	14.2 ± 13.1	1.4 ± 2.7	6.4 ± 3.5	11.1 ± 5.5	9.3 ± 7.4
BP 534	36.0 ± 8.5	11.0 ± 4.2	2.5 ± 0.7	10.6 ± 7.8	14.0 ± 5.6	3.5 ± 4.9
BP 936	33.0 ± 1.4	15.5 ± 0.7	3.5 ± 3.5	8.0 ± 1.4	11.0 ± 7.1	5.5 ± 2.1
Local	21.5 ± 13.7	15.1 ± 8.9	4.1 ± 8.4	9.9 ± 1.7	23.5 ± 12.2	26.3 ± 11.4

Note:
PrimBr = number of primary branches
PBrFruit = number of primary branch fruiting
SBrFruit = number of secondary branch fruiting
Bch/PBr = number of bunch/primary branch
Fruit/Bch = number of fruits per bunch
Pin/Bch = number of pin head fruit per bunch
SD = standard deviation

3.2. Deficiency Symptoms

Yellowing leaves in particular at mature leaves were found in all plots showing symptoms of nitrogen deficiency. Symptoms of nitrogen deficiency were also commonly found in farmers' coffee as shown in a survey report by Yuliasmara and Erdiansyah [18]. Another leaf yellow symptoms found in the farm particularly in FTC farm indicated another nutrient deficiency (Figure 1). The symptoms were originating from older leaves and generally found on mostly entire plant. The indication of the magnesium (Mg) deficiency was: Faint marginal chlorosis with sunken, yellow-brown to light brown necrotic spots developing in a wide band along margins; interveinal chlorosis evident in affected leaves, particularly along the midrib [19]. Moreover, wide band of marginal necrotic which was the common symptom of potassium deficiency in coffee leaves was also found at prolonged stage. We consulted the symptom of yellowing and spot necrotic of leaves sample to Mr. Joko Prasetyo from The Laboratory of Plant Diseases of Lampung University to confirm that the symptoms were not due to plant diseases.

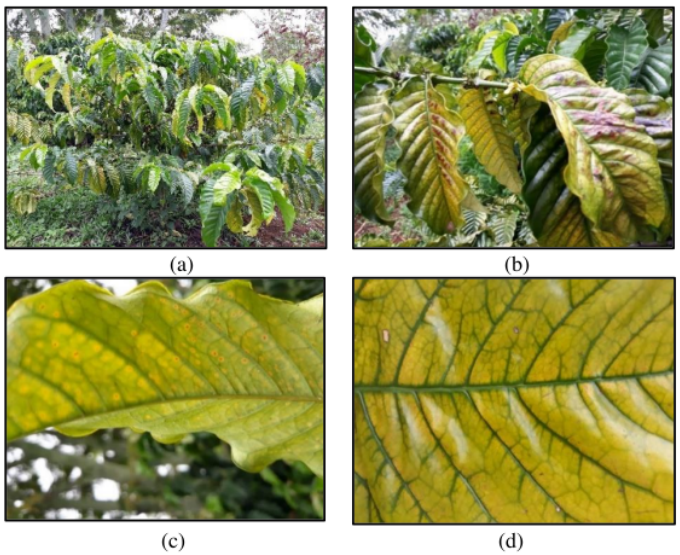

Figure 1. Yellowing leaves as N deficiency symptom (a), advance symptom with wide band of necrotic showing combining symptom of Mg and P deficiency (b) early symptom of Mg deficiency with yellow spots and necrotic (c), yellowing between the veins in older leaves showing symptom of Mg and deficiency N (d)

The results of soil sample analysis indicated low soil fertility showed by acidic soil, low-very low content of nitrogen, phosphate, potash, CEC, organic C, exchangeable Natrium and Calcium, magnesium, and Mangan but high Al and Fe (Table 2) according to the standard of Balai Penelitian Tanah [20]. The results of leaf analysis were N 2.08% and P 0.12% also indicating a low nutrient status according to Snoeck and Lambort [10].

Table 2. Results of soil analysis

Soil analysis	Value	Category[1]
pH H_2O	4.31	Very acidic
N total (%)	0.17	Low
P available (ppm)	1.01	Very low
K exchangeable (me/100g)	0.20	Low
CEC (me/100g)	8.25	Low
C organic (%)	1.99	Low
Al exch. (me/100g)	1.11	
Na exch. (me/100g)	0.03	Very low
Ca (me/100g)	0.61	Very low
Mg (me/100g)	0.11	Very low
Fe (ppm)	29.8	High
Mn (ppm)	1.84	Low-medium
Zn (ppm)	0.32	
Texture		
Sand (%)	24.76	
Dust (%)	13.62	
Clay (%)	61.62	

[1]Balai Penelitian Tanah [20]

3.3. Dieback Symptoms

Disorder symptoms commonly found in FTC farm and farmers' farm was die-back of shoots and branches (Figure 2) that might be associated with physiological causes. We found no borer insect in the dieback branches. It could reveal nutrient deficiency, over-bearing, poor shade tree cover and poor drainage. Die-back also might be occurred due to over-bearing (over bearing die-back), less nutrient availability, less assimilate during fruiting and harvesting. Chaves et al [12] reported that assimilation supply and demand associated with die-back syndrome was correlated by leaf to fruit ratio. According to DaMatta et al [11] although dieback might be associated with pathogens and insects, but it was not a primer cause. Occurrence of dieback was associated with a complex cause including environmental stresses, starvation of nutrient, and heavy bearing. Over bearing pushed depleting of starch reserves that needed for shoot and branches growing.

Under poor soil fertility and less proper maintenance, coffee trees grew slowly and leaves were yellowing. Weed cover was dominated by perennial grasses such as *Paspalum conjugatum* and Brachiaria sp indicating that weeding was not well managed and shade cover was poor. Shade of legume trees in particular provided ecosystem service for better coffee growth and yield [21]. After planting, young coffee trees were slow growth and some trees were dying. At the age of 6 years, coffee stand was only 44.2% remaining. After 3 times of yielding, coffee trees were showing symptoms of shoot dieback, branch dieback, or both. Replanting of death trees with new seedling was not much helpful. The replanted young coffee remained to grow slowly.

Coffee yield was also low which was only 0.05 ton ha^{-1} at the first yielding (at 3 years old), 0.25 ton ha^{-1} at the second yielding, and 1.01 ton ha^{-1} at the third yielding while showing dieback. Safitri [7] reported that coffee farms yield in Pagar Alam Sub-district, neighbour of Semendo was more than 1 ton/ha, mostly (60%) the local farmers produced 1-2 tons of coffee per year; while 23.33% of the farmers produced > 2-3 tons of coffee, 10% of the farmers produced > 3-5 tons of coffee.

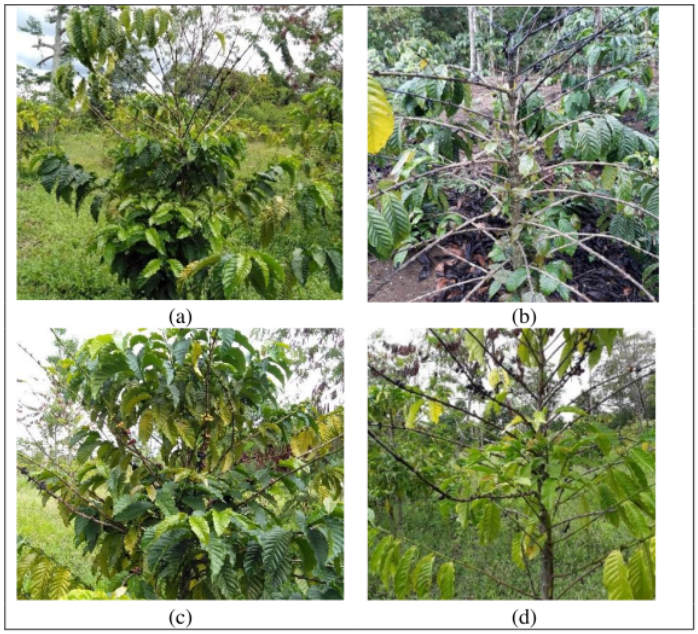

Figure 2. Symtoms of shoot dieback with medium (a) and high severity (b) and branch dieback with medium (c) and high severity (d)

Coffee plants exhibit a typical development of plagiotropic branches which consisted of non-fruiting branches and fruiting branches [22] as basic to define dieback symptoms. Dieback can occur on non-fruiting plagiotropic branches (shoot dieback) and on fruiting plagiotropic branches (branch dieback). We calculated branch dieback incidence at sample plots were 62-100% with severity score 1.0-2.5. We also found shoots dieback incidence was 15-50% with severity score 1.0-3.0. This finding indicates that most sample trees were more susceptible to branch dieback than to shoot dieback. Its symptoms ranged from low up to high severity. However, the local coffee clone showed a better tolerance on the branch and shoot dieback. This indicated that local clones were more adaptable to local agro-climate, had higher yield and long-live of coffee trees. Farmers cope with dieback by pruning and grafting of orthotropic branches using plagiotropic branches or *tak-ent* grafting [16] that resulted in strong lateral growth, known as umbrella type of branching, and high yielding coffee trees [23].

Table 3. Dieback incidence and severity

Robusta clone	Branch dieback		Shoot dieback	
4	Incidence (%)	Severity score	Incidence (%)	Severity score
BP 358	100	1.4	30	1.5
BP 409	100	1.1	36	1.0
BP 436	94	1.7	31	2.2
BP 534	100	2.5	50	1.0
BP 936	100	1.0	30	1.0
SA 237	69	1.4	15	3.0
Local	62	1.4	15	1.6

Our observation on leaf symptoms of nutrient deficiency, slow plant growth, dieback incidence, plant death, and low plant population supposed a failure of coffee establishment induced by low soil fertility

and poor plant management. Farmers in Lampung have local knowledge of coffee establishment after land clearing of shrub or old coffee field to improve young coffee growth. They incorporated coffee planting with intercropping of vegetables until coffee plants achieved bearing. When planting vegetables, farmers did soil tillage, applied manure and fertilizer, sprayed pesticide, and hand weeding which influenced better growth of young coffee [24]. Under the intercropping system, coffee trees were well established without any symptoms of nutrient deficiency and dieback.

4. Conclusions

The results of soil analysis and visual symptoms showed a deficiency of macro nutrient including N, P, K, and Mg that coincident with high incidence of dieback symptoms, particularly in branch dieback. We observed that branch dieback incidence was 62-100% with severity score 1.0-2.5 and shoots dieback incidence was 15-50% with severity score 1.0-3.0. Local coffee clone showed a better tolerance on branch and shoots dieback and higher yield potential based on number of fruits and pinhead fruit per bunch. The results of observation on leaf symptoms of nutrient deficiency, slow plant growth, dieback incidence, plant death, and low plant population showed as a failure of coffee establishment induced by low soil fertility and poor plant management.

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