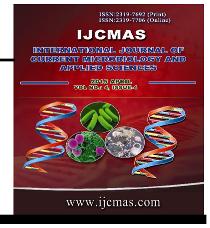

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Original Research Article

Prediction of the Effect of Deforestation Followed by Intensive Vegetables Cropping Systems on Population Density and invitro Ability of Phosphorhizobacteria in Tropical Highland of Bali Island, Indonesia

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A B S T R A C T

Population density of phosphorhizo bacteria known to be different between natural forest and agricultural lands. In the present study, the differences were quantified between natural forest land and the adjacent agricultural lands covered by a fertile Andisolin a tropical highland. The first study on this field of knowledge in Bali and probably Indonesia aimed to determine the effect of either deforestation followed by cropping systems orcropstype onthe population density and in vitro ability of phosphate solubilizing rhizobacteria (PSB)in dissolving phosphor (P). The density of PSB population was enumerated by the pour plate method while dissolving ability of P wasestimated according to either P solubilisation index (SI)or the amount of dissolved P_2O_5. Rhizosphere of natural forest plantswas inhabited by $26.20x10^6$CFU.g^{-1} dry soils of PSB with an average $Ca_3(PO_4)_2$dissolving ability at9.64 ppm P_2O_5 and SI of 1.94. The decline of PSB population density ofintensive agricultural soils comparedwiththe adjacent natural forests amounted to50.23%, 31.21%, and 26.56%, respectively for the soil in monoculture of lettuce, monoculture of leek and mixed strip intercropping systems. Ability to dissolve P by PSB was generally 29.90-43.47%loweron intensive agricultural soils than natural forest soils. Among the major vegetables types cultivated in the selected agriculture lands, rhizosphere of carrots were colonized by the significant highest number of PSB, while the least was in the rhizosphere of potatoes. The conclusion of this study were (1) deforestation followed by intensive vegetable cultivation activities substantially decrease PSB population density and its ability to dissolve P, (2) monoculture cultivation system with a lower dose of fertilizer as well as mixed stripintercroppingsystems harboring rhizosphere PSB both inhigher population density and in vitro ability to dissolve P, and (3) the carrot planthad the possibility of improving the density of PSB in intensive agricultural land.

Keywords

Rhizosphere, phosphate solubilizing bacteria, natural forest, cropping systems, vegetable fields

Introduction

Phosphorus (P) is the most important macro nutrient after nitrogen for plant growth (Donahue et al., 1990). The total content of P in the soil rangingfrom 200 to 3000 ppm

(Harrison, 1987) but less than1%that can be immediately utilized by plants (Richardson et al., 2009) because most of orthophosphate ions bound by soil fractions (Gyaneshwar et al., 2002; Hao et al., 2002). The availability of soil P and crops production mostly enhanced by fertilization but the increase of accumulated P fertilizer in soil begins to be criticized. Therefore, the use of phosphate solubilizing microbes (PSM) then widely studied to make efficient use of P fertilizer and mine P that accumulates in the soils (Harrison et al., 1972; Marra et al., 2011; Sharma et al., 2013).

PSM is a group of microbes which are capable of dissolving P of mineral and organic form through the activity of enzymes, protonation, and release of organic acid compounds and chelate agent (Nahas, 1996; Kim et al., 1997). Some fungi and bacteria were published to be capable of solubilizingsoil P (Narsian and Patel, 2009; Alia et al., 2013). PSM was found to be associated with various types of plants (Baon et al., 2012; Keneni et al., 2010; Sharma et al., 2012) at varying ecological types (Harrison et al., 1972; Gupta et al., 2007; Chitrapriya et al., 2013; Paul and Sinha, 2013). They inhabit different ecosystems types with a high variation of population densities of between 10^3 and 10^9 (Yahya and Al-Azawi, 1989;Naher et al., 2013). Beside fungi the group of bacteria capable of solubilizing P (PSB) was also extensively studied. PSB population known to be affected by cropping systems (Kim et al., 1998), while the environmentconditions also influence the efficiency of P dissolution by PSB (Taiwo and Ogundiya, 2008). Microenvironmentalvariations due to the diversity of root exudates excreted by various crops are probably related to the degree of PSB colonization. Root exudates are the primary energy source for soil microbes (Naher et al., 2009) which selectively favor microbial colonization in rhizosphere zone (Shi et al., 2011) and affect the production of organic acids by PSB (Hwangbo et al., 2003).

PSB is very potential to be developedasa biological fertilizer because it can increase P uptake,growth and crops production (Hameeda et al., 2008; Lara et al, 2013; Surapat et al., 2012). PSB inoculant is generally applied at a much higher population density than natural populationpresent in soils (Igual et al., 2001;Sabaruddin et al., 2010) for improvement of soil P uptake as well as plants growth and yields. Unfortunately, the population of exogenous beneficial microbes rapidly declined after its application on soils (Jacoud et al., 1998). Therefore, the empowerment of indigenous PSB would be better andan attempt should be considered to maintain the PSB community in the soils.

Numerous studies on PSBhave beenintensifiedfor several decades. However, little attention has paid to the the PSB associated with the rhizosphere of forest and vegetables plants(Mohan and Rhadakrishnan, 2012;Alia et al., 2013),particularly with respect to deforestation and agricultural expansion that most prevalent in the tropics since mid 20th century (FAO, 2012). The processes in upland areas can lead to land degradation (FAO, 2011). Tropical natural forests are world resources for genetic diversity (CBD, 2010) which reported contain some beneficial soil microbes (Jasper, 2007)including some groups of microbes capable of dissolving P (Mohan and Rhadakrishnan, 2012; Raj and Cherian, 2013; Raj et al., 2014). Forest conversion often causes important changes of soil properties (Neill et al., 1997; Post and Kwon, 2000;Carney et al., 2004; Kara and Bolat, 2008) and decrease the diversity and abundance of soil organisms (Atlavinyte, 1964; 1965). In fact, soil microbes are recognized to play someimportant roles in functioning of soil ecosystem (Nannipieri et al., 2003).

Vegetables are known to be micronutrients sources of food and are of economically valuables. Vegetables provide much higher income and job per hectare than staple crops for low capital farmers (Johnson et al., 2008). Most of vegetable crops preferred lower temperature (Ali, 2000).This preferenceis one of the main reasons for expansion of vegetables production to the highlands and for Indonesian country, this is the nowadays strategic issue. However, the effect of deforestation and intensive agriculture on the population density and the ability of PSB have not been well documented. Thus, this study was aimed to explore the changing of population density and ability of rhizosphere PSB caused by deforestation followed by intensive agriculture activities with highlight on vegetable cropping system in tropical highland. Prediction was done by comparing the density of the PSB population between natural forest land and the adjacent lands of intensive vegetable production. The comparison among vegetables crops were also conducted to determine the most suitable crop type in maintain the native PSB population in intensive agricultural soils. The knowledge is important for reference in designing the necessary land management in accordancewiththe opinion of Jasper (2007) who stated that the proper land management to enhance the beneficial soil microbes is highly recommended.

Materials and Methods

Description of Selected Study Sites and Sampling Locations

The selected study sites were located at an altitude of 1200-1500 m above sea level in Bedugul, Bali Island, Indonesia. The soil on theresearchareawas classified to the soil family of *Mollic Ustivitrands*, *medial isohyperthermic*according to USDA Soil Taxonomy and Classification Systemand C3 Oldemann climate type system with 5 consecutive months each for dry and rainy seasons (Adnyana, 2006; Nugroho, 1997). In the former time, the study siteswere a tropical natural forest that part of it had been gradually converted to agriculture land mostly for vegetable production more than 70 years ago. The selected study siteson the present study were including land use types of natural forest and the adjacent dry land vegetables cultivationlands. Undisturbed natural forest land was covered by a variety of forest plants at a density of 125 trees.Ha^{-1} (Sumantera, 2004), while agricultural land cultivated with some highland vegetable crops. Vegetables cultivatedlands were groupedinto 3based on cropping systems performed for the last 7 years. They were :the monoculture of lettuces (*Lactuca sativa* L.), monoculture of leeks(*Allium porum*L.) and mixed strip intercropping ofleeks, carrots (*Daucus carota*L), chilli (*Capsicum annuum*) and celery (*Apium graveolens* L. Dulce). In monoculture system, a short rotation of main crops with other crops was also conducted (such as local carrots and potatoes) for 1 planting period with planting area of <25%. Each plant required fertilizer with varying amounts. The following was the order of the highest to lower need of chemical fertilizers for plants cultivated in the study sites :potato>chili> celery> leek>lettuce>carrot.

Collecting and Preparation of Soil Samples

Triplicates soil samples were collected from the plant rhizospheres on both land uses, including each vegetable crop on eachcropping systems. Approximately 0.5 kg of rhizosphere soils were compositely taken at a depth of 0-30 cm. All soil samples were brought separately in labeled plastic bags to the laboratory. Soil samples free of roots and debris were passed through2 mm sieve size and was later stored at 5 ° C prior to analysis.

Enumeration of Population Density of PSB

PSB population was enumerated using pour plate method in Pikovskaya medium supplemented with tricalcium phosphate as the sole source of P (Pikovskaya, 1948). Each 1 ml of 10^{-4} and$10^{-5}$of soil dilutions in sterile saline solution (0.85% NaCl) wascultured on solid Pikovskaya medium in petri dish. The petri dishes were incubated at 27°C for 5 days and colonies showing halo zone then counted. Three colonies were randomly selected from each soil sample then purified and stored in slant agar medium.

Estimation of in vitro P Solubilisation by PSB

Estimation of in vitro P dissolving ability of PSB was carried out according to Edi-Premono et al. (1996). In the qualitative analysis, onemilliliter of each liquid culture containing 10^8 CFU.ml^{-1} PSB of selected colony was spotted in a solid Pikovskaya medium and incubated at a temperature of 27°C. The diameter of colonies and halozone formed were measured on day 5. The quantitative capability of dissolving P by PSB was measured based on the amount of P_2O_5 dissolved in Pikovskayabroth medium.One milliliter of the same cultures as proceed abovewas grown separately in 50 ml of Pikovskaya broth in a 125 ml Erlenmeyer flask. The cultures were incubated in a horizontal shaker (100 rpm and 25°C). After 72 hours, the liquid cultures were centrifuged at a speed of 10,000 rpm for 20 minutes. ThpH of the supernatant was then measured with a pH meter, while the amount of P_2O_5 dissolved in the medium was quantified according to phospho-molybdate blue colour method (Murphy & Riley, 1962).

Statistical Analysis

The effect of land uses and plant types on PSB population density and ability to dissolve P was analyzed by General Linear Model of Mannova (p=0.05). Least significant difference test was applied to differentiate the mean value among observed variables (p=0.05). The development of ecological groups based on population density and the ability of PSB was generated with hierarchical grouping analysis. Statistical analysis was proceed using 20th version of SPSS software system.

Results and Discussion

PSB can be found in variety ofterrestial ecosystems and associated with numerouskinds of plant (reviewed by Sharma et al., 2013). In this study, PSB rhizobacteriawas found throughout the natural forest land and agricultural lands, but the population density and the ability to dissolve P varied among land use types and among vegetable crops.

The difference of Population Density and in vitro Ability of Rhizosphere PSB between Natural Forest Land and Vegetable Cultivation Lands

Rhizosphere area of natural forest plants were inhabited by 26,02x10^6CFU.g^{-1}dry soils of PSB (Table 1). The PSB population densityfall within the range of the total PSB population in the forest in other parts of Indonesia(Suliasih and Widawati, 2005; Widawati and Suliasih, 2006).The difference between the PSB population density of natural forest land in Indonesia was assumed to be due to differences in the soil properties. The soil under this study was classified as Andisol (JunusDai and Rosman, 1970; Nugroho, 1997; Adnyana 2006) while the soil in the Halimun Mountain was classified as Latosol (Djuansyah, 1997) which was equivalent to Alfisol, Ultisol and Oxisol according to USDA Soil Taxonomy and Classification System.

The average ability of native rhizosphere PSB of natural forest plants in dissolving tricalciumphosphate were indicated by 1.57 cm of halo zone diameter, 1.94 of SI and 9.64 ppm P_2O_5 dissolved (Table 1). The diameter of halozone formed by PSB of natural forest land was in the range generated by PSB isolated from Halimun Mountain forest that ranges from 0.8 to 2.5 cm (Widawati and Suliasih, 2006). Compared with the SI value of PSB from other natural forest that had been reported (Muleta et al., 2013), the SI value of PSB natural forests in Bedugul was slightly lower.

Intensive vegetable plantation on deforested lands showed significant lower population density of PSB and their ability to dissolve P compare to PSB in the adjacent natural forest land ($p<0.05$). However, no significant difference was observed on colony size of PSB between those land uses ($p>0.05$). The range of PSB population density in intensive agricultural lands were 50.23- 26.56 % lower than PSB in natural forest land. Unlike the rhizosphere PSB population density, the effect of agricultural activity was relatively diverse on the ability of PSB in dissolving P (Table 1). The difference of native PSB population density and their ability among land use types in this study supported Sharma et al. (2013)'s report which stated that the type of land use affect the microbes community. However, the pattern of PSB population change due to land transformation ever published was inconsistent and reports for land conversion of natural forest to tropical highland vegetable cultivation land was still very limited. This research result was the first in Bali and probably in Indonesia which predicts changes in population density and the ability of dissolution of PSB P because of deforestation, followed by intensification of vegetables production in the highland zone.

PSB population density was lower in agricultural land than natural forest land which in this study was consistent with that published by Gupta *et al*. (1986), but in contrast to those reported by Naher*et al*. (2013). Contradiction of these results with the findings of Naher*et al.* (2013) allegedly due to differences in soil fertility status. Andisol soil of Bedugul highland had quite good physical and chemical fertility despite having a total-N content which was classified as low. In those conditions, nutrients and organic materials were assumed not a limiting factor for growth and development of PSB community. Those conditions were different from the study site of Naher*et al*. (2013) which was a soil deficit of macro nutrients.

Deforestation and agricultural intensification followed by changes in vegetation cover soil, microclimate conditions and soil properties according to the type of land use. Compared with changes in the land use types, the shift of microbial community composition was more influenced by specific changes in edaphic properties, especially pH and nutrient status (Lauber et al., 2008). In line with Lauber et al. (2008), Jecus et al. (2009) proved that the soil pH changes due to land conversion in the

Amazon tropical forest greatly affect bacterial community composition. However, it was apparently not the case in this study due to the average differences in soil pH between the natural forest land to agricultural lands only 0.33 points (unpublished data). Therefore, a decrease in population density and ability to dissolve P in vegetable cultivation area could be under the influence of other factors that were not identified in this research, for instance toxic effect of agrochemicals being used. Intensive agriculture systems characterized by intensive use of pesticides, herbicides and synthetic fertilizers can cause changes in the physical, chemical, and biological soil properties (Dick, 1992). Agricultural activities in the study area were characterized by intensive used of those agrochemicals (no data records for the dose of agrochemicals had applied). Application of agrochemicals, especially pesticides might be associated with the population density declines of PSB as a response to changing of environmental conditions for microbial growth. According to Turco et al. (1994), soil microbes are very sensitive to external disturbances in their habitats. Some research shows the diversimpact of pesticides on soil microbial communities. The application of pesticide can substantially affect populations and activity of PSB (Sethi et al., 2012) and biochemical processes including dissolution of soil P (Niewiadomska, 2004) because of the negative impact of pesticide on the synthesis and metabolism of both enzymes and proteins (Boldt and Jacobsen, 1998; Srinivasulu and Rangaswamy, 2014). Some pesticides increased activity of enzymes and ATP levels (Shukla and Mishra, 1997; Megharaj et al. 1999), the opposite may decrease> 90% of the phosphatase activity of *Klebsiella sp* and *Pseudomonas putida* (Ahemad and Khan, 2011; 2012) at 3 times of recommended dose. Therefore, the lower of PSB population density and ability on this agricultural soils than the adjacent natural forest soil was suggested partly due to the negative effects of pesticides applied by local farmers.

In order to determine the effect of cropping systems on the population and activity of PSB, thena comparison was made between the cropping systems. Differences in the cropping system being applied lead to a noticeable variation in population density and the ability of PSB (p<0.05).The decline magnitude of rhizosphere PSB population density and dissolution ability of P were different among cropping systems (p<0.05). The largest decrease in the PSB population density compared with natural forest (50.23%) was found in the land of monoculture lettuce, followed by the land of monoculture leek (31.21%) and the lowest on the land under mixed intercropping systems (26.56%). Deforestation and intensive agricultural cultivation generally also followed by decline in ability to solubilize P by PSB in the range from 29.90% to 43.47% except on lettuce monoculture land (Table 1). The difference cropping systems in the area of research had been done since the last 7 years because of economic, technical and social consideration. Differences in the cropping system turned out to cause a noticeable difference in population and the ability of PSB (p<0.05). This was contradictory to that ever published by Azzis *et al*. (2012) and Santa-Regina *et al*. (2003) that the local PSB resilient enough so that the effect of cropping systems was relatively short for population density differences of PSB. According Azzis *et al* (2012), PSB population was significantly higher in pasture land and rangeland compared with monoculture soil only in the first year of sampling. On the other hand, Santa-Regina *et al*. (2003) reported that the number of soil

PSB population was significantly different on several compositions of cover crops for 3 seasons except in the fall. It was different from the local PSB in Bedugul agricultural land which were likely to be sensitive to changes in the environment, especially the chemical properties of different soil between cropping systems (unpublished data) The difference between the population and the ability of PSB in Bedugul seemed to be controlled by soil properties in accordance with the opinions of Fierer and Jackson (2006). However, the distribution of the bacterial communities was potentially very site-specific and varied as stated by Alele *et al*. (2014) so that observation was further carried out at the level of plant types.

There were substantial differences observed in the ability of rhizosphere PSB origin of different cropping systems (p<0.05). PSB inhabiting rhizosphere of continuous leek and strip intercropping systems showed ability to dissolve P successively lower by 79.67% and 29.88% (p<0.05), respectively compared with PSB isolated from natural forest. Interestingly, the dissolution of P by PSB which was isolated from the rhizosphere soil of lettuce monoculture was 75.93% higher than the PSB isolated from natural forest. Dissolution of P by PSB was highly depend on the activity of phosphatase enzymes and excretion of extracellular organic acids produced by the PSB. Although toxic effect of pesticides potentially influence microbial population and ability (Niewiadomska, 2004; Sethi et al., 2012), it seemly not the main cause of variability in P solubilizing activity by PSB among cropping systems because all agricultural fields on this study had been treated with those chemicals. Thus, the main factors affecting the difference ability of PSB among cropping systems in this study was remained unknown and needs to be further investigated. There were three necessary possibilities left to be addressed in continuing the present study, namely : (1) PSB with higher P dissolving capability possibly eliminated from leek monoculture system and mixed strip intercropping, (2) The present PSB in the two cropping systems had lost some ability of P solubilization due to changes in land use types, and (3) There was any exogenous PSB with much higher cap abilityto dissolve P successfully struggle in monoculture fields of lettuce.

Results of our study showed different pattern of PSB response over different land use types based on the selected variables had been observed. Generalization of variables respond then further apparently important in determining the proper land use systems in order to maintain the native PSB communities in the soils. Land use clustering using hierarchical analysis had elucidated three ecological groups arising from the study area. Land of leek monoculture and mixed strip intercropping systems were considered to constitute one ecological group (group 1), while the lettuce monoculture land and natural forest was divided to group 2 and group 3, respectively. This finding means that soil monoculture cultivation system of lettuce had the relative nearest population density and PSB ability with natural forest so that the planting system can be applied to maintain the local community of PSB. In an effort of improving the population density of indigenous PSB, then the effect of different cultivated vegetable crops over PSB population and ability then mainly examined.

The difference of Population Density and in vitro Ability of Rhizosphere PSB among Selected Plant Types

Soil microbial communities are closely

related to plants (Duineveld et al., 2001; Smala et al., 2001) because variations in root exudates produced by different plant species (Mittal and Johri, 2007) selectively facilitate the composition of microbial communities in the rhizosphere (Jha et al ., 2014). The plant selectivity to PSB colonization was proven in this study as indicated by the high variation of PSB population density and ability among vegetables crops cultivated in each cropping systems (Table 2). All the vegetable plants observed were colonized by PSB. The range of the population density of PSB was between 4.83 and $36.74x10^6$ $CFU.g^{-1}$. The density of PSB population was lower than mostly reported for vegetable crops by Alia et al. (2013) that ranged between $8x10^5$ and $1.3x10^9 CFU.g^{-1}$ dry soils. Although all of the vegetable crops harboring PSB population in different density, their number were possibly not high enough to support their function in improving soil P availability and plant growth. An optimum population of PSB density must be required for agronomic purposes. Sabaruddin et al. (2010) through laboratory-scale study found that the optimum population number for enhancing the availability of P in Ultisolin Sumatra was $1x10^9 CFU.g^{-1}$ dry soil. An adequate soil management system might be useful to increase the population of the soil PSB. For examples by introducing PSB into the soil or rotating crops more suitably for habitat of PSB. In a limited availability of novel PSB to be applied, rotation of the more suitable crops as habitat for the native PSB could be preliminary studied.

Changes in PSB population density in the selected cropping systems potentially induced by short rotation of suitable vegetable types other than the main crop. According to some reports (reviewed by Nannipieri et al., 2007), plant types would cause different effects on rhizosphere microbial communities. Justin et al. (2012) published that the cropping pattern was affecting the composition and relative populations of bacteria and fungi. Alia et al. (2013) reported the considerable difference of crop types with the highest population density of phosphobacteria among vegetable fields in Pakistan, although those crops were cultivated in all studied fields. They specified variation of PSB among vegetables crops in three different places (Mansehra district, Taxila area and Islamabad) without indicating the actual cropping systems. This study further addressed the effect of crop type's rotation in each cropping systems to PSB population and ability. The results of this study showed a greater influence of crop types over cropping system on PSB population size developed in the rhizospheres ($p<0.05$). In the monoculture of lettuce, short rotation with carrots and potatoes did not significantly change the total number of PSB population ($p>0.05$) but the highest ability of rhizosphere PSB to solubilized P found in carrot plants (Table 2). In contrast, short rotation crops changed the population density of rhizosphere PSB in monoculture of leeks and mixed strip intercropping systems. PSB population density was found significantly higher on carrots rhizosphere ($p<0.05$) in both cropping systems. In the mixed strip intercropping system, the highest colonization of PSB also found in the rhizosphere of carrot plants while PSB population density in this cropping system was significantly different among croptypes (Table 2).

The highest PSB population density was found in the rhizosphere of carrot plants as a short rotation plants on the entire cropping systems, whereas the lowest was on a short rotation crop of potatoes in the monoculture land of lettuce and onion welch. The crops list from the highest level to the lower population density of PSB on vegetable crops arising from this study was as follows: carrots (rotation in monoculture of lettuce and onion welch) >leek (rotation in mixed strip intercropping) > lettuce in monoculture >leek in monoculture > chili in the mixed strip intercropping > celery the mixed strip intercropping > potato rotation in monoculture of lettuce > rotation potato in monoculture of onion welch. Our results verified that PSB population density was higher in the rhizosphere of crops that receive lower amounts of fertilizer, e.g. carrot, onion and lettuce. In the level of the plant types, the phenomenon was different from that reported by Hu et al. (2009) and Naher et al. (2013). Hu et al. (2009) revealed that the PSB population density increased in plots treated with P fertilizer wich was mainly in the form of organic fertilizers. Naher et al (2013) stated that the PSB population number was higher in rice plants that received a complete fertilizer treatment. The inconsistency was likely related to different soil fertility status. In the other hand, the in vitro ability of PSB to dissolve P did not differed among crop types except for carrots, forest plants, leek and potatoes (Table 2). Unexpectedly, forest land which had high quantities of rhizosphere PSB population did not have the highest potential to dissolve soil P.

Based on the potential number of PSB population and its ability to dissolve P, the suitable host plants for maintaining native PSB community can be ranked into 5 groups. The first group with the highest PSB potential was carrot plants grown as a crop rotation in monoculture of lettuce, the second group was monoculture of onion welch, group 3 was a mixture of forest plants, group 4 was a type of vegetable crops with low fertilizer inputs, and group 5 is the type of vegetable crops that require the most high fertilizer inputs. Thus, carrot crops were potential for use in maintaining and improving the indigenous PSB populations in the soil and at the same time keeping the PSB potential in dissolving P.

Table.1 Population Density, Colony Diameter, Halo Zone Diameter and in vitro Ability to Solubilize P of Rhizosphere PSB Origin of Natural Forest and Vegetables Production Lands

Land uses	PSB Population Density (x 10^6 CFU.g^{-1} dry soils)	Colony Diameter (cm)	Halo Zone Diameter (cm)	Solubilisation Index	Dissolution of P_2O_5 (ppm)
Natural Forest	26,02 ±5,26 a	0.77±0.32 ab	1.57±0.84 a	1.94±0.42 a	9.64±0.17 b
Lettuces in monoculture	12,95 ± 1,43 c	0.60±0.03 ab	1.10±0.04 a	1.87±0.02 a	16.96±0.66 a
Leeks in monoculture	17,90 ±1,72 bc	0.87±0.00 a	0.87±0.04 a	1.06±0.03 b	5.45±0.13 d
Mixed strip intercropping	19,11 ±1,03 b	0.50±0.01b	0.72±0.03 a	1.46±0.03 b	6.76±0.17 c

Description : Mean values followed by different letters on the same colomn indicated significant differences of the respective mean values according to Least Significant Differences Test ($p<0.05$). Values are given as means ± SD for triplicate samples

Table.2 Population density, colony diameter, halo zone diameter and in vitro ability to solubilize P of rhizosphere PSB origin of plant types

Cropping Systems	Plant Types	PSB Population Density (x 10^6CFU.g^{-1} dry soils)	Colony Diameter (cm)	Halo ZoneDiameter (cm)	Solubilisation Index	Disolution of P_2O_5 (ppm)
Natural Forest	Forest Plants	26,02±2,00 b	0,77±0,32 b	1,57±0.84 a	1.94±0.42 ab	9.64±0.17 b
Monoculture of Lettuces	Lettuces	14,31±1,59 c	0.60±0.05 bc	1.10±0.05 ab	1.83±0.07 bc	8.94±0.14 bc
	Potatoe	10,32±1,61 c	0.70±0.05 bc	1.10±0.05 ab	1.59±0.09 cd	7.17±0.25 d
	Carrot	15,26±1,27 c	0.50±0.00 c	1.10±0.05 ab	2.20±0.10 a	34.76±1.95 a
Monoculture of Leeks	Leek	13,88±2,22 c	1.20±0.05 a	0.90±0.05 b	0.75±0.07f	4.96±0.10 e
	Potatoe	4,83±1,07 d	0.70±0.05 bc	0.80±0.10 b	1.15±0.12 e	4.59±0.27 e
	Carrot	36,74±5,23 a	0.70±0.05 bc	0.90±0.05 b	1.29±0.17 de	6.80±0.11 d
Mixed strip intercropping	Carrot	31,76±5,08 a	0.50±0.05 c	0.70±0.05 b	1.40±0.04 de	7.09±0.23 d
	Leek	20,99±2,24 b	0.50±0.05 c	0.70±0.05 b	1.40±0.04 de	7.25±0.25 d
	Chili Pepper	12,56±2,00 c	0.50±0.05 c	0.70±0.05 b	1.41±0.22 de	4.75±0.12 e
	Celery	11,13±1,71 d	0.50±0.05 c	0.80±0.05 b	1.61±0.06 cd	7.96±0.34 cd

Description: Cropping system referred to agricultural system only, while natural forest wasreffered as the former land use type

Mean values followed by different letters on the same colomn indicated significant differences of the respective mean values according to Least Significant Differences Test ($p<0.05$). Values are given as means ± SD for triplicate samples.

Many researchers have been conducted to examine the population and the ability of PSB in dissolving soil P. However, little attention was paid to the PSB population and ability in relation to deforestation followed by intensive vegetables cultivation under different cropping system and crop types. Through this research, we provide scientific evident that 7 years of intensive vegetable cropping systems in deforested tropical highlands land could lead to a major changed on population density and in vitro ability of native PSB.

Intensification of agriculture led to a noticeable decrease of rhizospheric PSB population densityto50.23%, 31.21%, and 26.56% respectively for monoculture of lettuce, onion monoculture and mixed strip intercropping systems. The lowest rhizosphere PSB population density of agricultural land was found in lettuce monoculture system (12.95x10^6 CFU.g^{-1} dry soils), while the highest (19.11x10^6 CFU.g^{-1} dry soils)was present on mixed strip intercropping system.

The ability to dissolve soil-P of PSB also generally significantly lower between 29.90 and 43.47% in the intensive agricultural lands. Among the major vegetables types cultivated in the agricultural fields, carrot rhizosphere were inhabited by the highest population density of PSB (31.76-36.74x10^6 CFU.g^{-1} dry soils), while the least was present on rhizosphere of potatoes(4.83-10.32x10^5 CFU.g^{-1} dry soils). The highest ability to solubilized P shown by rhizosphere PSB originate of monoculture of lettuces land particularly from cultivated carrots. Thus, monoculture farming systems with lower fertilizer input and mixed strip intercropping harboring higher PSB population density and had higher ability to dissolve P.

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