Short Communication

Faba Bean: a Promising Crop for Realizing a Healthier Potato Cropping System in the Dieng Highlands

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Abstract

Dieng Highlands of Central Java is a renowned potato production center in Indonesia due to its climatic suitability. Potato was introduced four decades ago and remains the main crop favored by farmers since then. After long and perpetual cultivation, agro-ecological problems that lead to reduced crop yield have emerged. In this paper, the potential of faba bean (*Vicia faba* L.) as a local resource of Dieng to help build a healthier cropping system is discussed. Faba bean is grown for tourism market demand yet considered second to potato. This legume, in symbiosis with *Rhizobium* bacteria and mycorrhiza, is capable of fixing nitrogen and making phosphorus and potassium more available in the soil. Having cold hardiness characteristics, faba bean is best to grow during the cold season in July or August. It may also help reduce nutrient run-off due to its high phosphorus requirement and uptake. A proper inclusion of faba bean into the current potato cropping system, either grown together or in sequence, brings tangible benefits to the soil and other crops. Future challenges to this innovation include better understanding of nutrient dynamics under Dieng climatic conditions and soil types, further investigation of the potential contribution of other prevailing crops, and improved knowledge on and use of local farmers' perceptions and resources regarding this innovation.

Keywords: Dieng Highlands, cropping system, faba bean, potato

Abstrak

Dataran tinggi Dieng di Jawa Tengah menjadi pusat produksi kentang yang ternama di Indonesia karena kondisi iklimnya yang sangat mendukung. Kentang diperkenalkan ke petani setempat sekitar empat dekade yang lalu dan telah menjadi tanaman utama sejak saat itu. Setelah masa produksi yang panjang dan terus menerus, persoalan-persoalan agroekologis yang memicu turunnya hasil panen muncul di lahan. Di dalam tulisan ini akan dibahas potensi kacang babi (*Vicia faba* L.) sebagai salah satu kekayaan lokal Dieng untuk membangun sistem pertanaman kentang Dieng yang lebih sehat. Kacang babi umumnya dibudidayakan sebagai salah satu produk makanan ringan bagi wisatawan, tetapi pamornya masih kalah dibandingkan kentang. Tanaman ini, ketika bersimbiosis dengan bakteri *Rhizobium* dan cendawan mikoriza, memiliki kemampuan untuk mengikat nitrogen dari atmosfer dan meningkatkan ketersediaan fosfor (P) dan kalium (K) di tanah. Tanaman ini tahan dingin sehingga dapat menjadi pilihan budidaya yang tepat selama periode dingin di Dieng: yaitu pada bulan Juli dan Agustus. Selain itu, budidaya kacang babi berpotensi mengurangi pencucian hara tanah karena kebutuhan dan serapan hara P oleh tanaman relatif tinggi. Integrasi tanaman kacang babi ke dalam sistem pertanaman kentang, baik dalam bentuk tumpang sari ataupun rotasi, dapat membawa manfaat bagi tanah dan tanaman lainnya. Tantangan di masa yang akan datang dalam mewujudkan inovasi sistem pertanaman ini adalah pemahaman yang lebih dalam tentang dinamika unsur hara pada kondisi klimatik dan variasi tanah Dieng, kontribusi agroekologis tanaman-tanaman lain yang telah ada di lahan, serta persepsi dan sumber daya petani setempat.

Kata Kunci: Dataran tinggi Dieng, sistem pertanaman, kacang babi, kentang

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Introduction

Dieng Highlands is the largest potato producer in Central Java. Potato production takes place for almost the whole year, except during the cold season in July and August when the temperature reaches 3°C. Potato is sometimes rotated with cabbage, cauliflower, carrot, leek, and celery. Other important economy sectors in Dieng are tourism and plant-based food and beverages production. Some exclusive products are sourced from *carica* (*Carica papaya*), *tamarillo* (*Solanum betaceum*), *purwoceng* (*Pimpinella pruatjan* Molkenb), and faba bean (*Vicia faba* L.). Nonetheless, they remain second to potato.

Potato production in many farms uses excessive and imbalanced amount of inputs. Sutriadi (2013) reported that nitrogen (N) fertilization was far higher than phosphorus (P) and potassium (K) application. Inorganic N use was 312 kg ha^{-1} while the recommended amount was only 185 kg ha^{-1}. Pesticides are widely used to combat potato cyst nematode, black cutworms, and beetles (Marks, 2012). Farmers mix various yet often unnecessary pesticides and schedule routine spraying: once every two, three, or four days (Bondansari *et al*., 2011).

In early 1980, potato yielded 30-60 ton ha^{-1} but nowadays the average yield could only achieve 17 ton ha^{-1} (Arbangiyah, 2012; Maharani, 2012). Sutriadi (2013) found that N fertilization is not the major factor affecting this change. Most farms are located on the slope with steepness degree of more than 8%. Slope is originally easily eroded and vulnerable to nutrient run-off. The practice of contour-perpendicular ridges exacerbates erosion. The erosion level in Dieng is very heavy; more than 480 ton of annual soil loss per hectare (Sukristiyanti *et al*., 2013). Perpetual erosion depletes soil fertility, restricts crop choices, and increases fertilizer demand to maintain yield (Morgan, 2005).

The soil is actually capable of retaining P compounds yet erosion transports such nutrients to water bodies. This leads to eutrophication and reduction of water quality. Piranti *et al*., (2015) reported cultural eutrophication in dam Mrica of Dieng due to very high P loading into the water. The total amount of P entering this lake was 11,526.11 kg per year; potato farming contributed 23% of it.

Erosion-triggered soil fertility loss and nutrient run-off may cause gradual decline of potato yield. At the same time, excessive fertilizers and pesticides use without yield increment indicates abundant foreign substances in the soil. This may lead to perturbation of biochemical processes and nutrient cycling regulated by soil biota (Altieri and Nicholls, 2003). This agronomic practice is no longer healthy for the people, the environment, and the economy. Therefore, it is necessary to propose a new direction of cropping system that brings benefits to producers, consumers, and surroundings.

Faba bean, a local richness of Dieng known as *kacang babi* or *kacang* Dieng, has agroecological potential benefits which can help build a healthy cropping system (Table 1). Currently it is marketed as a typical snack of Dieng. Its potential use is actually much wider. The seeds can be used as meat extender, skim-milk substitute, vegetable, and stock feed. The straw can be processed into bricks. It is also potential for medication of Parkinson's disease and hypertension due to its levodopa content (Singh *et al*., 2013). The contribution of faba bean is neither optimized in the local cropping system nor researched intensively. Therefore, this paper will discuss the potential of this crop to innovate and realize a healthier potato cropping system in Dieng.

A prominent trait of faba bean is its capability to fix atmospheric N in the presence of symbiosis with *Rhizobium* bacteria in the roots. Its fixation may range from 15 to 648 kg N ha^{-1} (Köpke and Nemecek, 2010). Faba bean can even accumulate nitrogen for an extended period: up to 315 kg N ha^{-1} after 110 days (Singh and Bhatt, 2012).

The inclusion of faba bean in agroecosystem could be beneficial for N credit in the soil as this legume utilizes less soil N thus this nutrient can be conserved or used by other crops; this is called N-sparing (Dalias, 2015). Moreover, legume contributes to soil N balance through excretion of N compounds, nodule and root decomposition as well as aboveground residue decomposition at the end of growing season. This process may release high amount of

plant-available N to the soil (Balota and Chaves, 2010).

Faba bean can grow in different soil textures. Its compatible *Rhizobium leguminosarum* strains are present in most arable soils. Unlike other legumes, faba bean can maintain high fixation rate despite of abundant soil N availability (Rose *et al*., 2016; Köpke and Nemecek, 2010). In many farms in Dieng where excessive inorganic nutrients are present in the soil due to the imbalanced fertilization, faba bean's ability should not be perturbed thus crop will not underperform.

This crop is tolerant to acidic soils (Singh and Bhatt, 2012) and contributes to soil acidification due to the proton released to the soil during its N_2 fixation process (Köpke and Nemecek, 2010). In acidic ambience, more soil P is soluble thus available for plant. This is important for faba bean as it requires high amount of P to create Adenosine Tree Phosphate (ATP) needed for roots biological function (Ribet and Drevon, 1996). It is advantageous for the neighboring crops having similar acidity preference e.g. potato. As faba bean residues breakdown may lead to higher alkalinity, this acidification will later be counteracted (Yan and Schubert, 2000) thus crops may not suffer from very acid condition.

Faba bean builds symbiosis with mycorrhiza (Köpke and Nemecek, 2010). Mycorrhizal symbiosis is known to enhance solubility of soil P, K, and some micronutrients which lead to larger nutrients uptake by roots. Inoculation of Arbuscular Mycorrhizal Fungi including its combination with *Rhizobium* in pot experiments improved faba bean's growth and yield (El-Wakeil and El Sebai, 2007). This indicates that the functional roles of both beneficial microorganisms are likely not disturbed in the presence of each other.

Moreover, faba bean is known for its cold hardiness. The hardiest cultivar can tolerate temperature of -10 to -15°C without serious injury (Singh *et al*., 2013). Despite of the unknown information on the cold-hardiness of local faba bean, this crop is strongly a better alternative during the frost season in Dieng when potato and other vegetables rarely survive the low temperature. This pronounced opportunity, if properly implemented, can reduce crop failure and farmer's financial loss.

The inclusion of faba bean into the prevailing potato monoculture in Dieng could deliver tangible benefits to both crops. Combined cultivation of faba bean and potato in the same field during the same period, known as intercropping, will primarily induce better P and K uptake by potato. This is due to the enhanced P and K solubility in the soil stimulated by nitrogen fixation process, rhizosphere effects, and mycorrhizal activities. The limited application of P and K fertilizer in most farms can be complemented by faba bean functional roles. This will lead to a more adequate P and K supply as well as more balanced nutrients uptake for crops.

Moreover, faba bean can help reduce P loading to water bodies as it absorbs high amount of P. In the area where erosion is likely to take place, intercropping faba bean seems to be a feasible way to reduce P run-off.

Sequential crops cultivation, known as rotation, provides gradual nutrient supply from faba bean to non-legume (e.g. potato and vegetables). Nutrients accumulated in faba bean's stand will be broken down more properly by decomposers when crop residue is incorporated into the soil or used as fertilizer. It is reported that faba bean residue could deliver up to 270 kg N ha^{-1} to soil and around 100 kg N ha^{-1} originates from belowground parts (Rochester *et al*., 1998). This amount is much higher than the abovementioned requirements for potato in Dieng.

While the dynamics and rate of N release vary depending on soil characterisitics, microbial activities, and crop genotypes, faba bean growing under optimum conditions will contribute significant N balance to the soil. Proper incorporation into the soil will even trigger higher nutrient release. This can be translated that growing faba bean in Dieng is theoretically sufficient to substitute the current use of excessive inorganic N fertilizer.

Furthermore, unlike inorganic fertilization in which nutrients are released rapidly to the soil thus is prone to run-off; the nutrient supply from faba bean residue will be released more slowly depending on decomposers' activity. The gradual release of nutrient can be used by potato

or other succeeding crops in moderation during different growth stages.

In order to create this innovative cropping system, some contextual challenges must be tackled in the future. The main purpose of incorporating faba bean is to attain the best nutrient management so that 1) organically or internally-sourced nutrients can be sufficiently and timely available, 2) external inorganic inputs will be efficiently used, 3) nutrient loss will be reduced, and 4) stable soil activities can be maintained. It is then important to assess temporal biochemical nutrient dynamics in soil and plants when faba bean is grown with and in rotation with potato. Soil erosion and potential run-off will also bring effect to the physical disperse of nutrients. These dynamics are strongly affected by climatic and soil characteristics thus further investigation should be specified to Dieng conditions.

Moreover, it is also advisable to look at the contribution of other prevailing cash crops (vegetables, herbs, fruits). Their contribution may appear in the form of recycling nutrients, suppressing pests/diseases/weeds, or improving soil conditions. All these knowledge are essential to establish feasible cropping system innovation which satisfies nutrients requirement during different growth stages. In the pursuit of this innovation, it is very thoughtful to fairly embrace farmers' perceptions and resources.

Table 1. Agroecological potential benefits of faba bean when included into cropping system.

Main characteristics	Agroecological potential benefits
Biological N fixation	Providing N for beans production (Köpke and Nemecek, 2010) Reduced N fertilizer use (Dalias, 2015)
Rhizosphere acidification effects	Enhancing P and K solubility due to acidification in the rhizosphere (Zhang *et al*., 2015; Yan *et al*., 2014)
Mycorrhizal symbiosis	Enhancing solubility and uptake of P, K, and other micronutrients (Qiao *et al*., 2015; Köpke and Nemecek, 2010)
Cold hardiness	Conserving the soil during cold season

Conclusion

The agro-ecological problem of intensive potato cultivation that has resulted in gradual yield declines necessitates an innovation of healthier cropping system that brings benefits to people, environment, and economy. Faba bean as the local crop of Dieng possesses many superiorities that, if properly integrated into potato cropping system, will help build this innovation. The future challenges to this end are further investigation of nutrient dynamics in soil and plant as resulted from the new mixed cropping systems under local climatic and soil conditions, better understanding of the potential contribution of other prevailing crops to system performance, and improved knowledge on and use of farmers' perceptions and resources.

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