5th International Planters Conference 2006
26 – 27 June 2006
Putrajaya Marriot Hotel, Putrajaya, Malaysia

# Concept and Implementation of Best Management Practice for Maximum Economic Yield in Oil Palm Plantations

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**Abstract**

*There are substantial opportunities to increase yield and profitability on existing land through the implementation of Best Management Practice (BMP) in oil palm estates. However, plantations are challenged with the identification and implementation of suitable BMPs that would promise greatest financial return with existing human and capital resources. This paper summarizes results from several years of development and field testing of a generic BMP concept that has been introduced at larger scale in several estates in Indonesia and Papua New Guinea. Major emphasis is given to portraying the process from the evaluation of most promising BMP practices in representative blocks to the introduction of practices at commercial scale. The evidence-based BMP concept is now promoted through a new set of collaborative projects in Southeast Asia providing assistance in training, agronomic and economic data analysis, and planning for wider scale implementation of BMP at a commercial scale. The BMP concept is part of a larger framework for the ecological and sustainable intensification of oil palm production with integrated solutions for the management of agronomic information.*

**Keywords**: *best management practice, decision support, ecological intensification, oil palm*

## INTRODUCTION

The importance of the palm oil industry in global vegetable oils production today is undisputed. In 2005, palm oil accounted for 30.7% (34.3% if palm kernel oil was included) of the total production of 109 million metric tons (t) of 7 major oilseed crops (soya, rapeseed, cottonseed, groundnut, sunflower, coconut), but oil palms occupied only 4.2% of the total harvested area of 217 million hectares (ha) of these 7 crops (Bek-Nielsen, 2006, citing Oil World 2006 Estimates for season Oct/Sep 04/05). The palm oil industry is a key component of the national economy in both Malaysia and Indonesia, which together accounted for 85% of total global palm oil production in 2005 (USDA, 2006). For example, palm oil products earned Malaysia between 27-30 billion ringgit (approx. US dollar 7-8 billion) in export revenues each year in the period 2003-2005 (MPOB, 2006). The industry is also widely acknowledged to play an important role in national socio-economic development in both countries, providing a good livelihood for the rural populace and stable employment to a large segment of the workforce.

Of late due to escalating prices of fossil fuels, new demand has been driven by strong interest in palm oil-based bio-diesel production, and with a recent surge in investments in palm bio-diesel plants in the region (Anon, 2006a-c), palm oil production in Malaysia and Indonesia is set to expand even further in the years to come to meet the anticipated new requirements (Ovais Subhani, 2006; Zaidi Isham, 2006). However, palm oil yields in Malaysia and Indonesia remained stagnant for the last 20 years (FAOSTAT, www.fao.org), and unless greater effort is undertaken to increase productivity per unit planted area, the pressure on marginal land will increase. Total planted area already exceeds 4 million ha in Malaysia (MPOB, 2006), and 5 million ha in Indonesia (Derom Bangun, 2006), so further expansion of oil palm cultivation in both countries is likely to involve the exploitation of less favourable environments, with the consequence that national average palm oil yields will be lowered further.

While the biodiesel-driven demand is a bolster for palm oil prices, long term real prices have been declining at an average rate of 3% a year (Fry, 1988, cited by Teo, 2006). The rise in prices of fossil fuels, the catalyst for the new interest in biodiesel, has on the other hand driven up costs of production. Given the inverse relationship between long term trends for palm oil price and cost of production (Davidson, 1993), the oil palm industry is caught in a cost-price squeeze that will worsen if yields are not improved on existing planted land.

As palm oil is traded globally as a commodity in competition with many other oils and fats, plantations have no control over its price. Profitability is thus dependant upon having a low cost of production, which in turn depends on achievement of high yield through high productivity from inputs and assets employed, and efficiency of crop processing.

To remain profitable in the long term, plantations need to improve productivity of land and human resources. Many plantations, though, put too great emphasis on short-term cost control and reduction, at the expense of investing in more knowledge-based yield improvement strategies that will enhance longer-term and sustainable business viability. This short-term 'cost control' mindset exists because of the time it takes to demonstrate, and the difficulty in quantifying, yield improvements from investments in agronomic inputs in ongoing commercial operations.

After decades of research in Malaysia and Indonesia, a great wealth of knowledge is already available in the oil palm industry that provides ample opportunities for plantations to reap higher yields. Knowledge-intensive technologies are now available to planters that can enable more effective management and analysis of available information. This will allow better estimates of economic yield targets, and achievement of these targets through more effective use of inputs and adoption of best management practices (BMPs) in an ecologically sound manner (Griffiths and Fairhurst, 2003; Witt *et al*, 2005). However, many companies are still unable to cross the 'IT threshold' that will allow more effective use of information already available, and the better knowledge-based decision-making that comes with it, to improve performance.

The evidence-based BMP approach will lower the challenge presented by this 'IT threshold', and help change the short-term 'cost control' mindset holding back plantations from achieving higher yields.

## BEST MANAGEMENT PRACTICES: AN OVERVIEW

Over decades of formal (i.e. research trials) and informal (practical trial and error) experimentation, BMPs have been developed for the whole chain of plantation operations from land appraisal to crop processing. There is no lack of publications to guide planters on the requirements for enhancing yields. Good overviews of the broad measures needed have been recently presented by Gan (2005) and Teo (2006), and practical field handbooks (Rankine and Fairhurst, 1999a-c) are available to guide new planters where in-house GAP (good agricultural practices, or group agricultural policies) are not.

All BMPs are, directly or indirectly, meant to produce high yields, though modifications may be needed for optimum, or maximum economic, yield under any given situation. BMPs related to harvesting, crop recovery and processing, have a direct and immediate impact on yield and quality of produce. Other BMPs have indirect and later impacts, but are nonetheless as important for the achievement of optimum yield.

BMPs related to planting material production and selection will determine the genetic yield potential of each source (i.e. seed producer) or type (i.e. conventional DxP hybrid seeds or clones from tissue culture) of planting material. BMPs related to land appraisal, land development, and field planting determine the maximum attainable yield (Y-max as later defined in this paper) for a particular planting material planted at a given location. BMPs related to post-planting maintenance aspects influence the actual attainable yield.

## YIELD GAPS

A large gap currently exists between average palm oil yields in Malaysia and Indonesia, and the highest achieved yields. For example, Bek-Nielsen (2006) estimated that in the better part of the last 10 years, there was a gap of some 40% between the average yield of palm oil in Malaysia (3.5-4.0 t $ha^{-1}$) versus the top yielding Malaysian producers (average palm oil yield of over 5.5 t $ha^{-1}$). Corley (2005) contended that by raising the national average palm oil yield in Malaysia and Indonesia to the level of the best companies, forecast demand for palm oil for the next 15 years could be met without any further increase in planted area.

Even in the top producing plantation groups, a significant gap can exist between the average group yield and the highest yielding estates. An example of this is provided by the IOI Group, one of the largest oil palm growers in Malaysia with over 135,000 ha of mature oil palms in 2005, which reported an average palm oil yield for the whole group just a shade below 6.0 t $ha^{-1}$ (from average fresh fruit bunch (FFB) yield of 27.6 t $ha^{-1}$, and average oil extraction rate of 21.6%) for their financial year ended 30$^{th}$ June 2005 (IOI Corporation Berhad, 2006), an achievement that was attributed to "years of concerted efforts and commitment on good and quality management practices". Set against this high achievement, it was worthy to note that 41 of the IOI Group's 79 estates were reported to have yielded above 6 t $ha^{-1}$, with 15 of the 41 estates having exceeded 7 t $ha^{-1}$, and the highest yielding estate achieving 8.23 t $ha^{-1}$ (IOI Corporation Berhad, 2006). These statistics show a 23% gap between the group average yield and the average for the top 15 estates (with average palm oil yield of 7.36 t $ha^{-1}$), and a 38% gap against the top estate. This clearly indicates that even in a high achieving group, opportunities still exist for further yield improvement. Examples of high palm oil yields on an estate scale are also found in Indonesia, with Corley (2006, quoting communication from P.S. Baskett) reporting achievements in Sumatra in 2004 of 7 t $ha^{-1}$ from Padang Pulo estate (from an area of 1,170 ha) and 6.4 t $ha^{-1}$ from Aek Loba estate (from an area of 7,680 ha), with both estates producing crops with an oil extraction ratio of 25.5%.

A simple model (Figure 1) is given by Fairhurst *et al* (2006) to explain why many plantations achieve only 30-40% of the genetic potential yield (Y-max) for a particular site. **Y-max**, presently regarded as being within the range of 12-14 t $ha^{-1}$ (Corley and Tinker, 2003), is limited only by climate, planting material and the site characteristics that cannot be altered economically by management (e.g. soil texture) when all other factors are at optimal levels and all agronomic constraints removed, i.e.:

- the palm stand is at the optimal density, and established with high quality, well adapted planting material with no runts or unproductive palms.
- soil erosion and surface runoff is controlled by appropriate soil conservation structures (terraces, platforms, silt pits and bunds) and establishment of legume cover plants (LCP), and competition from weeds is eliminated by proper ground cover management from establishment through to maturity
- complete crop recovery is practised from the moment the palms are brought into production.

**Y-mey,** the maximum economic yield, is lower than Y-max. The difference in yield between Y-max and Y-mey (i.e. Yield Gap 1) may be 20% (Figure 1) or more, and is due to:

- deficiencies in the palm stand arising from sub-optimal planting density and/or inaccurate lining resulting in a sub-optimal palm canopy, failure to properly cull seedlings in the nursery, and to replace all runts and unproductive palms, and to infill gaps in the palm stand during the immature phase, and loss of palms due to pests and diseases

- permanent damage to the soil due to careless or inappropriate land clearing, such as soil compaction due to incorrect use of bulldozers for land clearing and soil loss due to uncontrolled surface run-off and sheet erosion because of failure to establish LCPs after land clearing
- Y-mey is usually achieved with less fertilizer than required to reach Y-max.

Y-mey is defined during plantation establishment and the economic yield ceiling is set once the palms reach maturity and the palm stand is fixed. If measures are not taken to minimize Yield Gap 1 during the plantation establishment and immature phase, yield and profitability will be limited over the whole lifespan of a planting.

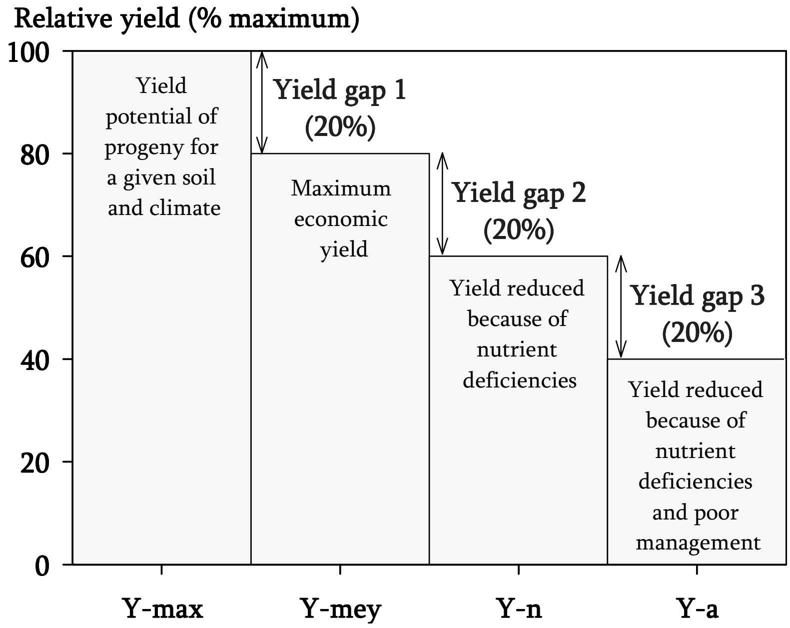


Figure 1. Example of the effect of nutrient and crop management on yield potential or maximum yield (Y-max), target yield (Y-mey), attainable yield (Y-n) and actual yield (Y-a). Adapted from Fairhurst *et al* (2006).

**Y-n**, the nutrient limited yield, is lower than Y-mey. The difference between Y-mey and Y-n (i.e. Yield Gap 2) may be 20% (Figure 1), and arises from failure to detect nutrient deficiencies and/or recommend optimal fertilizer rates. These failures are commonly due to:

- soil variability within the plantation not accounted for,
- un-representative leaf analysis data (because of failure to establish a grid of healthy palms for leaf sampling, mistakes in selection of representative leaf tissue for analysis, and defective or faulty analytical procedures),
- excessive reliance on leaf analysis results and failure to take visual leaf nutrient deficiency scores into account,
- failure to interpret agronomic data correctly for the purpose of determining fertilizer requirements, and
- lack of fertilizer response trial data for more accurate interpretation of leaf analysis results and determination of fertilizer rates.

**Y-a,** the actual yield, is smaller than Y-n. The difference between Y-n and Y-a (i.e. Yield Gap 3) may be another 20% (Figure 1), and is due to failures in general crop management, including incomplete crop recovery, failure to properly implement fertilizer recommendations, poor ground cover conditions and drainage, and uncontrolled outbreaks of pests and diseases.

The three 'yield gaps' as defined above and shown in Figure 1 demonstrates how plantations may only achieve as little as 40% of Y-max. Yield Gap 1 can only be minimized by applying meticulous attention to every detail of plantation establishment from the nursery until the onset of production. Reduction of Yield Gap 2 is the responsibility of the agronomist, who must inspect the fields and use all available data and analytical techniques to accurately determine nutrient requirements. Yield Gap 3 can be reduced by the planter, aided by the agronomist, through the formulation and strict implementation of field upkeep programs that ensure full crop recovery, correct application of recommended fertilizers, and effective control of pests and diseases.

## BEST MANAGEMENT PRACTICE (BMP) FOR MAXIMUM ECONOMIC YIELD

In a plantation comprising mainly mature palms there is limited scope to close Yield Gap 1 and therefore the aim must be to close Yield Gap 3 whilst simultaneously improving the diagnosis and correction of nutrient deficiencies (Yield Gap 2). At the same time, agronomists and managers must work together to establish a plan for implementation including:

- Step 1: Full inventory of information and yield constraints (palm stand, past yields, fertilizer use and pest and disease problems, soil type, climate information).
- Step 2: Identification of BMP measures and selection of pilot phase blocks.
- Step 3: Monitoring and evaluation of progress in pilot-phase blocks.
- Step 4: Plan for wider scale implementation according to results obtained in Step 3.

Yield gaps between BMP blocks and surrounding management units (blocks, or groups of blocks) can be directly linked to differences in crop recovery, canopy and nutrient management, and other agronomic BMPs. Several broadly-defined BMPs have been identified (Griffiths and Fairhurst, 2003, Witt *et al,* 2005; Fairhurst *et al*, 2006) that could be expected to produce the greatest increases in productivity across a wide range of growing conditions, climate and soils – they are listed according to priority as follows:

- Priority 1: Complete crop recovery through short harvesting rounds and collection of all detached fruits,
- Priority 2: Optimize growth and bunch production through quantitative canopy management (pruning, removal of unproductive palms),
- Priority 3: Optimize root function and nutrient uptake of palms through adequate moisture availability (drainage, water conservation), and
- Priority 4: Improve soil organic matter and optimize nutrient management (establishment of LCPs, complete recycling of crop residues (empty bunches, mill effluents), erosion mitigating measures, and maximizing fertilizer use efficiency).

Appropriate BMP(s) for a management unit can be identified based on analysis of the prevailing site conditions, and prioritized according to their expected impact on yield. A small number of blocks with BMP placed strategically in a plantation will provide a useful evidence-based showcase to:

- determine the site-specific maximum economic yield under optimal management conditions,
- estimate peak crop production (% annual crop in a single month) for planning mill capacity requirements,
- demonstrate the effect of management practices on crop performance and soil improvement (show case),
- train staff on the implementation of new practices, and
- test new technologies.

The importance of complete crop recovery can never be over-emphasized. All too often, crop losses are incurred due to failure to carry out complete harvesting at 10-day intervals. For example, Donough (2003) reported a yield difference of 2.1 t $ha^{-1}$ FFB in one year between 10-day and 15-day harvesting intervals in a carefully controlled study on 11-year old oil palms at Sandakan, Sabah, with 33.7 t $ha^{-1}$ obtained using the shorter interval compared to 31.6 t $ha^{-1}$ from the longer interval. The remainder of the estate block in which the study plot was located yielded 30.5 t $ha^{-1}$ in the same year, largely due to lower crop recovery compared to the study plot during the peak crop month when harvesting intervals in the estate exceeded 15 days. In such cases where yield achieved is already at a level currently regarded as 'high' (e.g. >30 t $ha^{-1}$ FFB), losses due to such crop recovery failures are easily overlooked as the un-recovered crops are never weighed and thus remain 'unseen' or un-recorded.

Failure to completely recover crops may be due to labour shortage (which may in turn be related to inadequate investment in housing), poor field upkeep and road conditions, inadequate transport capacity, or insufficient milling capacity. All of these factors must be integrated in an overall plan to eliminate yield gaps.

A water management, or water and soil conservation, plan must be designed and implemented to ensure adequate drainage, flood control, moisture conservation and soil erosion control. An early warning system must be implemented to keep the status of pests and diseases below economic thresholds. Detailed procedures for the maintenance and management of mature plantings are described in Turner and Gillbanks (2003) and Rankine and Fairhurst (1999c).

## THE IMPLEMENTATION OF BMP AT COMMERCIAL SCALE: A CASE STUDY

The first collaborative BMP project was established at Asiatic Persada (AP) in Jambi Province, Indonesia, in 2001. The plantation had been established between 1988 to 1989 but required extensive rehabilitation at the time of its acquisition by the present owners (CTP Holdings, previously Pacific Rim Palm Oil Limited) in 1999. Results from this project had been presented earlier (Griffiths and Fairhurst, 2003; Witt *et al*, 2005). The latest results up to 2005 (Fairhurst *et al*, 2006) are given below.

To recapitulate, seven representatives blocks, each about 30 ha and comprising a total of 210 ha (equivalent to about one block per 1,000 ha), were selected for rehabilitation in October 2001 (Griffiths and Fairhurst, 2003). All blocks were inspected and agronomic and management constraints listed and developed into an action plan. Works were implemented in the following step-wise sequence:

- All woody weed growth was removed and harvest paths and palm circles were established by hand weeding and with herbicides.
- Logs and other debris not cleared at planting were removed from all paths and circles.
- Footbridges were installed to provide complete access.
- Soil conservation measures (palm platforms, contour paths) were installed to reduce soil erosion losses and surface water run-off and provide access for harvesting and fertilizer application.
- Field drains and improved drain outlets were installed using an excavator fitted with a 'V' bucket in low-lying areas affected by temporary and permanent inundation.
- Supply palms were planted in vacant low-lying areas after installing drainage to bring each block to a complete stand of palms.
- A one-time application of 300 kg P2O5 $ha^{-1}$ as reactive phosphate rock (RPR) over the palm inter-rows.
- 40 t $ha^{-1}$ empty bunches were applied to improve soil physical properties, supply nutrients, and prevent the loss of rock phosphate in surface water run-off.

- Shade tolerant LCP (*Calopogonium caeruleum*) was established by planting cuttings between each palm where empty bunches and RPR had been applied.
- Runts and other unproductive palms were poisoned out.
- Corrective pruning removed unproductive fronds and improved access for harvesting.

The total cost of the improved practices, including the cost of rock phosphate was US$ 220 $ha^{-1}$. As soon as full access to each block was completed (paths, circle weeding) the harvesting standard was changed to 7-day intervals to ensure complete crop recovery, and strict supervision ensured that there was no crop loss due to incomplete loose fruit or bunch harvest and collection. Except for the ameliorative application of RRP, standard estate fertilizer recommendations were used in all BMP blocks.

Management of non-BMP blocks only included improved fruit bunch recovery, standard fertilizer application, and corrective pruning. Standard estate fertilizer recommendations were used in all blocks: 1.4 kg N $palm^{-1}$ as urea, 0.9 kg $P_2O_5$ $palm^{-1}$ as RRP, 1.95 kg $K_2O$ $palm^{-1}$ as potassium chloride, and 0.07 kg MgO $palm^{-1}$ as kieserite.

Yields increased much more rapidly in the BMP blocks compared to the non-BMP blocks in 2002, mainly due to much more rapid increase in bunch number (Figure 2). This was a direct impact of the focus on complete crop recovery by implementing strictly supervised harvesting on seven-day intervals. In remaining years until 2005 the main impact on yield was more due to increased bunch weight (Figure 2). This was related to improved palm nutrient status due to the soil rehabilitation program with empty bunches, rock phosphate and LCPs.

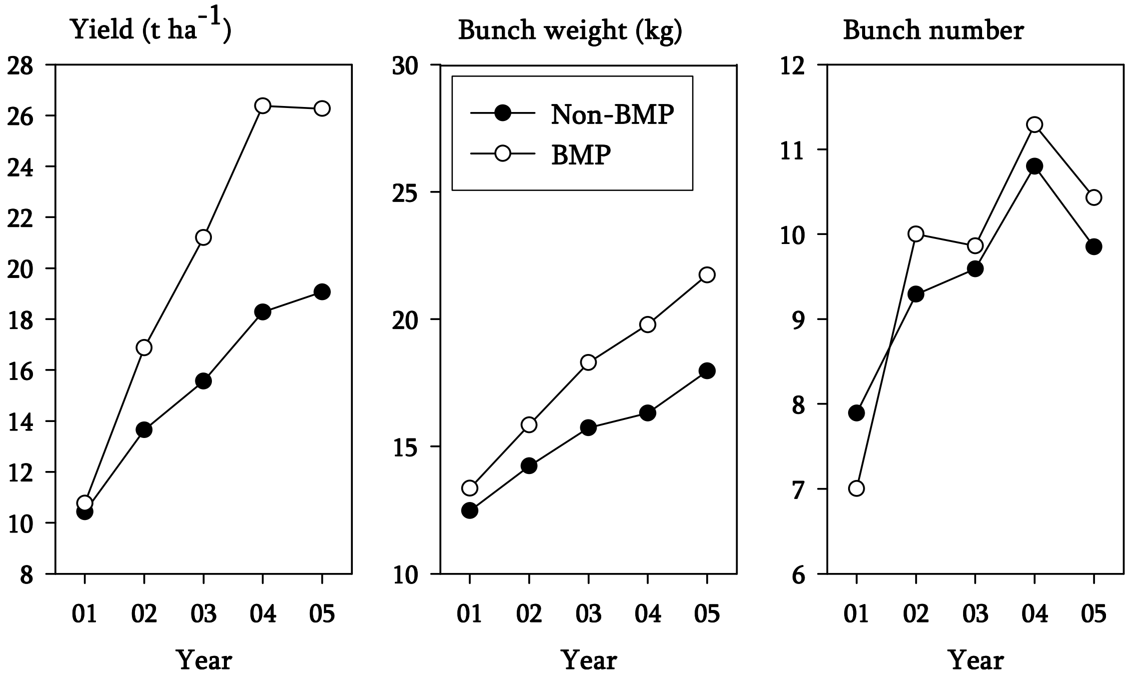


Figure 2. Yield, bunch weight and bunch number in BMP blocks (planted 1988-1991) compared with non-BMP blocks of the same planting years in Asiatic Persada, 2001-2005. Adapted from Fairhurst *et al* (2006).

Now, five years after the start of the project in 2001, yields appear to have stabilized at about 26 t $ha^{-1}$ in the seven BMP blocks implemented in the pilot phase (Figure 2).

In 2005, implementation of the same agronomic practices was expanded to cover a further 1,080 ha of old plantings in AP. With the success obtained todate in AP, CTP Holdings is presently implementing BMP projects to maximize yields progressively over 70,000 ha of plantations located in Sumatra, Kalimantan and Papua New Guinea.

## NEW COLLABORATIVE PROJECTS ON BMP

To build upon the success of the BMP concept in the initial collaborative project above, and to further validate the wider applicability of this evidence-based concept in the oil palm industry, the Southeast Asia Program (SEAP) of the Potash and Phosphate Institute/Potash and Phosphate Institute of Canada (PPI/PPIC) and the International Potash Institute (IPI) is now embarking on a new BMP program starting in 2006, in which the same generic concept will be applied in collaboration with six selected plantations in Indonesia and Malaysia.

Through the implementation of this new project, the SEAP aims to identify opportunities for achieving maximum economic yield under a wider range of conditions through the process of evaluation, collection of evidence, analysis and isolation of key success factors, and to develop plans for the wider-scale delivery of the concept. To achieve these objectives, the SEAP will collaborate with a wider spectrum of plantations with different ownership and management structures (e.g. family-owned, professionally managed corporation, or public company) and size and depth of operations (total land-bank, planted area, levels of involvement in post-production processing). An important consideration for the new BMP project is to cover a range of oil palm growing environments in Indonesia (north, central and south Sumatra; west, central and east Kalimantan) and Malaysia (Sabah and Sarawak). The most important consideration of all is the commitment of the plantation towards yield improvement.

At each participating site, a minimum of 5 blocks (at a rate of approx.1 block per 1,000ha) will be selected in the plantation to represent major production areas and growing conditions (e.g. soil type) for assignment as BMP blocks. A corresponding set of 5 neighboring blocks with comparable tree age and yield level will be used as reference (REF) blocks for comparison against the BMP blocks. Each set of one BMP and one REF block will serve as a replicate, and data collected can be analyzed statistically as a randomized block design.

An agreed set of BMPs will be implemented in each BMP block for the duration of the project. The core BMP will be a short harvesting interval of 7 days (4 harvesting rounds per month), to ensure that maximum possible yield is achieved in the BMP blocks. This will usually ensure that harvesting in the BMP blocks will be out of step with the rest of the estate, including the REF blocks, thus ensuring that yield recording on a block scale will be accurate. Nutrients shall not be limiting in BMP blocks – fertilizer rates will follow standard estate recommendations unless soil and plant analysis suggests a revision of recommendations. Management practices in REF blocks will follow the standard practice in the estate, and fertilizer rates are applied according to standard estate recommendations.

The selection of sites and collaborating plantations for this four-year project started in March 2006 and the first project site will commence activities in July 2006. Once sufficient results have been obtained, regional workshops including visits to the BMP blocks at the project site will be organized to facilitate the exchange of information among planters.

## THE OIL PALM PLATFORM

Best Management Practices form an integral part of the principles of crop and nutrient management along with evolving strategies for their implementation promoted by the Oil Palm Platform. The platform builds on efforts of individual oil palm agronomists and technical experts from selected companies and organizations interested in the integration of tools, technologies, and knowledge. A joint platform with non-members is provided with the new Oil Palm Portal (www.oil-palm.info). Members share a common vision that oil palm estates need to be economically feasible as well as socially and environmentally responsible to become part of a sustainable future of the oil palm industry.

Major objectives of the Oil Palm Platform are

- to assess the evolving needs of planters in crop and nutrient management,
- to exchange information and experience in crop and nutrient management,
- to provide information, technical references, guidelines and support to the oil palm industry,
- to generate, integrate, and aggregate tools, technologies, and knowledge, and
- to promote integrated concepts based on the five principles of crop and nutrient management concepts.

The Southeast Asia Program of PPI/PPIC-IPI (www.seap.sg) continues its long tradition of supporting planters through research, training, technology development, and publications in partnership with leading institutions and companies. The Oil Palm Platform provides us with an opportunity to further strengthen our efforts and we wish to increase our direct collaboration with estates in the evaluation, adaptation and improvement of technologies promoted by the Oil Palm Platform.

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