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Oil Palm Block Efficiency Indicator

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***Abstract*- Growers need to be creative in identifying techniques to monitor and understand planting material variation within and between blocks. Being creative does not necessarily mean being complicated. The Block Efficiency Indicator (BEI) is a simple, reliable and repeatable concept that fills a management gap allowing growers to identify which of five variables are influencing block-planting material efficiency, positively or negatively. BEI is a percentage calculation compiled by dividing actual values by theoretical values for planting density, yield, bunch weight, frond production, and block sex ratio. When actual values equal theoretical values, BEI is 100 and block-planting material is achieving its expected commercial potential. A reduction in average frond rate from 17 to 15 fronds/yr for example produces a BEI of 77.9, while a reduction in block sex ratio from 0.7 to 0.6 produces a BEI of 73.5, equivalent to a loss of 16 and 19 palms/ha respectively. When the effects were combined, BEI is 57.2, equivalent to a loss of 33 palms/ha. The Block Performance Indicator helps growers to understand cause and effect, allowing them to develop strategies to maximise production and efficiency.**

***IndexTerms*—oil palm (*Elaeis guineensis* Jacq.), Block Efficiency Indicator (BEI), planting density, yield, bunch weight, frond production, Block Sex Ratio (BSR)**

I. Introduction

Successful palm oil (*Elaeis guineensis* Jacq.) production requires a significant capital outlay and long-term commitment, generally 25 years per crop rotation. To maximise return on investment growers must not only choose the best planting material available, but also understand planting material performance. Growers often have no difficulty understanding the principals of productivity in financial terms, although many fail to understand, or comprehend differences as well as interdependencies of planting material productivity and efficiency. In basic terms, productivity is the ratio of output to inputs in production; efficiency on the other hand is a measurable value, quantitatively determined by the ratio of output to inputs. For growers, productivity without efficiency costs money.

Research has been pro-active in defining factors that benefit palm growth and productivity [1] [2]. The focus however has been more on yield intensification than on understanding block planting material efficiency. The difficulty for growers is that once planted, genotype and environment are out of their control. This only leaves management. Implementation of Best Management Practices (BMP) allows growers to maximise yield (tonnes Fresh Fruit Bunch (FFB)/ha) within the constraints of environment and genotype [2]. BMP is effective and logical from the commercial perspective however, the measure of productivity and efficiency or effectiveness is yield. In the eyes of the industry yield defines success, and it is easy to understand why.

Yield is a complex interaction of genotype, environment, and management, and on its own cannot determine efficiency. Low yielding blocks are not commercially desirable however; it is possible for a low yielding block to be more efficient than a high yielding block, especially when planting density, bunch weight, frond production, and block sex ratio are considered. High yields are the commercial objective and combined planting material productivity and efficiency are necessary to achieve it.

The proposed Block Efficiency Indicator (BEI) is a simple, reliable, and repeatable concept that uses readily available or easily obtainable data for performance analysis. It allows growers to make real time comparisons within and between blocks and planting materials under existing environmental and management conditions. It also provides valuable genotype and genotype x environment data for future planting material selection as well as helping to remove any prior misconceptions regarding palm growth and performance that may exist.

A. Block Efficiency Indicator (BEI)

BEI calculates the ratio of actual values for planting density, yield, bunch weight, frond production, and block sex ratio to theoretical values, expressed as percentage efficiency (Equation 1).

$$\text{BEI} = \frac{P_1}{P_x} \times \frac{Y_1}{Y_x} \times \frac{B_1}{B_x} \times \frac{F_1}{F_x} \times \frac{S_1}{S_x} \times \mathbf{100} \qquad \text{(Equation 1)}$$

Where:
$\mathbf{P_1}$ = actual number of palms/ha
$\mathbf{P_x}$ = theoretical (original) planting density - palms/ha
$\mathbf{Y_1}$ = actual yield in t/ha
$\mathbf{Y_x}$ = theoretical yield in t/ha
$\mathbf{B_1}$ = actual (average) bunch weight in kg
$\mathbf{B_x}$ = theoretical (average) bunch weight in kg
$\mathbf{F_1}$ = actual (average) frond production rate
$\mathbf{F_x}$ = theoretical (average) frond production rate
$\mathbf{S_1}$ = actual block sex ratio
$\mathbf{S_x}$ = theoretical block sex ratio

Theoretical and actual values need to be determined for planting density, yield, bunch weight, frond production, and block sex ratio.

II. Determining BEI values

Theoretical BEI values should be obtainable from the plant breeder, however if the breeder is unable or unwilling to commit to specific figures then a performance range might be the best option. If growers have established blocks, or are aware of existing blocks with the same planting material, then this may provide data for the development of realistic theoretical values. If using actual yield values to determine theoretical, then it would be appropriate to increase values by 10-20% so that BEI does not reach 100% and growers become complacent.

Irrespective of the data source, the objective is to determine baseline theoretical values that accurately represent the genetic potential of the planting material for each particular site. Theoretical values for each developmental stage would provide a more specific indication of efficiency. Maturity stages representing planting to 5 years, 6 years to 20 years, and 21 years through to clear fall would be a viable starting point. Theoretical values, once calculated should remain constant to ensure meaningful comparisons. This does not prevent fine-tuning provided recalculations were across the board. Actual values for planting density, yield, bunch weight, frond production, and block sex ratio will be readily available from management records, or easily obtainable through block sampling.

A. Planting density (palms/ha)

Planting density is a function of the number of palms planted (theoretical) or remaining (actual) divided by the total area planted. Differences between the two will likely be the result of deaths due to pest or disease incidence. Planting density is a measure of the amount of resources: light, nutrients, and moisture available to the palm so the greater a plant density the greater will be competition for available resources, and vice versa. Optimal planting density is a commercial balance between resource availability and demand.

It is important to count all palms, especially palms classified as non-productive as these are consuming available resources and affecting block performance. The actual number of palms present in the block is easily determined through a field census. In calculating planting density, it is important to use the original planting area. If the planting density is particularly low in some sections then treat these areas separately, but do not discard them. If treating poor performing areas as separate first assess the whole block irrespective of planting density, then assess areas where planting density is normal, and finally assess areas where planting density is poor. The relationship between poor areas expressed as a percentage of good area allows a more detailed palm performance assessment. FFB yields per palm may be greater in areas where planting density is low because of increased resource availability, so growers need to take care when reviewing results to prevent a biased efficiency outcome.

B. Yield (t/ha FFB)

Yield is the ultimate commercial objective so it is important to ensure all bunches and loose fruit are collected, and correct allocation of fruit to prevent bias. Theoretical site-specific yield values for individual planting materials are required and should be available from the breeder. Actual values for FFB yield will be readily available from harvesting data. If it is possible, determine planting density and yield for individual harvesting areas to allow more in-depth efficiency analysis.

C. Bunch weight (kg/bunch)

Bunch weight is a function of bunch structure and development, determined by interactions between planting material and environment. Theoretical site-specific bunch weight values for individual planting materials are an important component of the BEI and should be available from the breeder. To calculate actual bunch weight divide yield by total number of bunches harvested by number of harvest rounds. This data should be readily available through normal management practices.

D. Frond production (fronds/palm)

Frond production rates are not normally recorded, however they are an important calculation when determining BEI. Fruit is a function of frond production, within the constraints of sex ratio, so irrespective of palm numbers if there is no frond production there can be no fruit. Frond production rate varies in relation to environmental factors such as water deficit so oil palm is commercially drought susceptible, but naturally drought tolerance as it simply slows or even stops growth and development until soil moisture levels return to normal.

Average frond production rates are determined by counting the number of fronds in one spiral from the base of the palm to frond zero in the crown. Oil palm has two frond spirals, 8 and 13 but count only fronds in the eight spiral. It does not matter if the spirals are left-handed or right-handed. Multiply the numbers of fronds counted in one spiral by eight and divide by the age of the palms in years to determine average number of fronds per year for that palm. A 10% count of palms should provide an accurate representation of average frond production for the block, and if plotted on a block map will highlight any unusual patterns.

E. Block Sex Ratio (BSR)

BSR calculates an average sex ratio for block planting material so the greater the number of bunches harvested from a given area, the greater will be the sex ratio. Theoretical BSR values for individual planting materials are required and should be available from the breeder. Calculate actual BSR values from management records by dividing bunches harvested by planting density by number of harvest rounds.

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Once the theoretical and actual values are available, data validation is required.

III. Data validation

To validate actual data the values used in or derived from the formula must be consistent with management records or data sampled. The first step is to confirm actual yield using actual values of the other variables (Equation 2).

Yield (FFB t/ha)

$P_1 \times B_1 \times F_1 \times S_1 \div 1000$ **(Equation 2)**

If yield data validation fails then the error must be determined by independently working backwards through the formula for each variable: planting density (Equation 3), bunch weight (Equation 4), frond production (Equation 5), and block sex ratio (Equation 6).

Planting density (palms/ha)

$Y_1 \times 1000 \div B_1 \div F_1 \div S_1$ **(Equation 3)**

Bunch weight (kg/bunch)

$Y_1 \times 1000 \div P_1 \div F_1 \div S_1$ **(Equation 4)**

Frond production rate (fronds/palm)

$Y_1 \times 1000 \div P_1 \div B_1 \div S_1$ **(Equation 5)**

Block sex ratio (percentage fraction)

$Y_1 \times 1000 \div P_1 \div B_1 \div F_1$ **(Equation 6)**

If planting density, bunch weight, frond production, and block sex ratio values are valid, then yield is incorrect. A limitation of this technique is average bunch weight. If yield is incorrect then average bunch weight will be incorrect as it is a function of yield divided by number of bunches harvested divided number of harvest rounds. Accurate yield recording will eliminate any errors in average bunch weight. The situation becomes more complex if two or more variables are incorrect.

Once validation is complete, BEI is ready for calculation.

IV. BEI calculation and discussion

Calculation of BEI is relatively easy and straightforward. It is simply a matter of calculating the ratio of actual values to theoretical for each factor, multiplying the results together to express as a percentage (Equation 1).

Table 1 presents a range of examples using the following hypothetical theoretical values:

P_x = 136 palms/ha
Y_x = 35.6 t/ha
B_x = 22kg/bunch
F_x = 17 fronds/palm
S_x = 0.7 (70%)

With the exception of yield and BSR, the values presented as examples use whole numbers to simplify the calculations, in reality this would not be the case.

- Example 1 - multiplying planting density (136) x bunch weight (22) x frond production rate (17) x block sex ratio (0.7) and dividing by 1000 to convert kg to tonnes, a calculated yield of 35.6t/ha is obtained. Actual yield equals the theoretical yield (35.6t/ha) so BEI is 100 and the block planting material is achieving its full potential, or at least the expected commercial potential. Ideally, no block should have a BEI of 100 as it may promote grower complacency, better to be striving for continuous improvement through BMP.
- Example 2 – actual palm numbers are 130, only 96% of the theoretical 136. Consequently, yield is 34t/ha and BEI is 91.4. The loss of 6 palms per hectare is commercially important however, the effect is limited only to 6 palms and not the remaining 130 as is the case for the other factors. It is important for growers to understand that for every missing palm there is an associated commercial cost, although compensated for in greater access to available resources for palms at lower densities.
- Example 3 - actual bunch weight is 20kg, only 91% of theoretical 22kg so yield is 32.4t/ha and BEI is 82.7. Bunch weight is the factor with the highest degree of internal variation, not only in physical size, but also in fruit and oil quality and quantity so it is important to understand this aspect when using BEI as a measure of efficiency. Growers can benefit from improved understanding, especially regarding weevil pollination and fruit set.
- Example 4 – average numbers of fronds/palm is 15, only 88% of theoretical 17 fronds so yield is 31.4t/ha and BEI is 77.9. Frond production is important although growers are unlikely to have readily available data. In very simple terms if there is no frond production, there can be no inflorescences and no inflorescences means no fruit.

TABLE I. EXAMPLES OF DIFFERENT BEI OUTCOMES BASED ON CHANGES TO PLANTING MATERIAL VARIABLES

Palm variables	Examples						
	1	2	3	4	5	6	7
P_1 = actual number of palms/ha	136	130	136	136	136	136	136
P_x = original planting density	136	136	136	136	136	136	136
Y_1 = actual yield in t/ha	35.6	34.0	32.4	31.4	30.5	26.9	43.7
Y_x = theoretical yield in t/ha	35.6	35.6	35.6	35.6	35.6	35.6	35.6
B_1 = actual bunch weight in kg	22	22	20	22	22	22	27
B_x = theoretical bunch weight in kg	22	22	22	22	22	22	22
F_1 = actual frond production rate	17	17	17	15	17	15	17
F_x = theoretical frond production rate	17	17	17	17	17	17	17
S_1 = actual block sex ratio	0.7	0.7	0.7	0.7	0.6	0.6	0.7
S_x = theoretical block sex ratio	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Block Efficiency Indicator (BEI)	**100.0**	**91.4**	**82.7**	**77.9**	**73.5**	**57.2**	**150.6**

- Example 5 - block sex ratio is 0.6 (60%), only 85% of theoretical 0.7 (70%) so yield is 30.5t/ha and BEI is 73.5. It is important to understand that this is a block sex ratio and not an individual palm sex ratio so the greater the sex ratio the greater will be the number of palms that have produced bunches. BSR is not a measure of past or future sex ratio; it simply expresses the BSR at the time of data collection.
- Example 6 - actual data values from examples 4 and 5 are combined, yield is 26.9t/ha and BEI is 57.2. This example shows how the combined effects of different values can influence yield. It is very likely that when calculating BEI there will be multiple factors involved requiring deeper interpretation.
- Example 7 - actual bunch weight is 27kg, 123% of the theoretical 22kg so yield is 43.7t/ha and BEI is 150.6. This example shows that if actual values exceed theoretical, a BEI greater than 100 results. This anomaly may occur during periods when conditions are optimal. Irrespective of the underlying cause, theoretical values have been under-estimated so re-evaluation is required. BEI should always be less than 100.

The examples presented clearly show the impact that changes in planting density, yield, bunch weight, frond production, and block sex ratio have on BEI and on FFB yield. Growers need to understand the potential interactions and be able to interpret results. The BEI formula deliberately applies identical calculations for each factor i.e. same percentage losses for each factor produce the same BEI outcomes. This means that even though changes in some values such as block sex ratio might seem numerically very small, the commercial implications can be large. If BEI is less because of reduced bunch weight, frond production, or block sex ratio then growers can look to developing strategies, environmental or management to try to remedy the situation. If BEI is less because of missing palms, then options are limited and losses will continue for the life of the block planting material. Understanding cause and effect places growers in a better position to maximise production and efficiency whilst minimising losses.

V. Conclusion

The Block Efficiency Indicator is a simple, reliable, and repeatable concept designed to allow growers to monitor and characterise block plant material performance. Growers will be very aware of their block performance in terms of FFB yield, but not necessarily understand why planting material in one block is better than the next. Emphasis placed on productivity without understanding or comprehending differences as well as interdependencies of planting material productivity and efficiency cost growers money. BEI allows growers to identify which of five factors within or between planting materials are limiting production by reducing efficiency. BEI is not a tool for assessing management performance, although it will have value in helping to eliminate prior conceptions of block planting material performance. The Block Performance Indicator concept presented puts growers in a better position to maximise returns on their investment.

References

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