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Multiple-Criteria Decision Analysis for Effect of Shoot Growth at Difference Combination Nutrient Fertiliser NPK for Harumanis Mango

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ABSTRACT

It is vital to have the correct fertiliser arrangement for effective tree development, fruit yield, and essential fruit quality. The amount of fertiliser suggested with adequate nutrition will be maintained in the soil to supply the needs of the trees as they grow throughout the various growth stages. This study evaluated the effect of different combinations of Nitrogen(N), Phosphorus(P), and Potassium(K) on the vegetative flush physiology of Harumanis mango (Mangifera Indica. L). Single and combinations of N (511g), P(511g), and K(255g) fertilisers were used, which were N, P, NP, and NPK throughout May 2021. The results revealed that the minimum number of mature green leaves and a higher number of healthy panicles were observed in the NPK-treated plants. Moreover, NPK treatment showed the lowest malformation intensity percentage compared to other fertiliser treatments. The data were analysed to obtain the best regrowth pattern of shoots using Multiple-Criteria Decision Analysis (MCDA) techniques. The results on the pattern of regrowth after pruning when federalised with NPK fertiliser showed that the maximum percentage of total vegetative flush was 87.5% and the remaining 12.5% did not reach a satisfactory level according to the MCDA analysis.

Keywords: N, P, and K fertiliser; Soil application; Harumanis Mango; Vegetative Flushes; Multiple-Criteria Decision Analysis (MCDA)

1. INTRODUCTION

Mango is a popular tropical fruit in Southeast Asia, especially Malaysia. Mango, also known as Mangifera indica, comes in a wide range of forms and sizes. Due to its aroma, texture, and sweetness, Harumanis (Mangifera Indica) is the most prevalent mango cultivar in Perlis. Year after year, Harumanis's popularity grows and their retail price per kilogram has practically tripled compared to the other kinds. As a result of this situation, local farmers have been inspired to increase their Harumanis growing. One of the primary reasons why this Harumanis species is excellent to be grown in Perlis is due to the Monsoon Tropical climate. The fruits are harvested every year between May and June. Apart from the temperature, the soil, being a significant source of nutrients for the plants greatly influences Harumanis' growth. Nitrogen (N), phosphorus (P), and potassium (K) are the three most important soil nutrients [6][9]. Therefore, N availability is important for agricultural growth. Providing the optimal amount and fertilisers to the mango tree will supplement the tree's nutrient requirements. This study performed a field investigation on the impact of mango trees. The MCDA method was used to evaluate the multiple different criteria to achieve overall results.

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2. PROBLEM STATEMENT

For efficient tree development, fruit output, and essential fruit quality, proper fertilisation is critical. Therefore, it is critical to have a formulation to decide and obtain the appropriate amount and type of fertiliser, and the right time to give it to the tree [1][6]. To date, there is a lack of studies on the overall nutritional requirements of Harumanis trees. Currently, Harumanis farmers' techniques are solely based on their personal experience, which is very subjective. The target fertiliser will supply the soil with adequate nutrition to cater to the needs of the trees as they grow throughout the season [7]. To do this effectively requires an understanding of orchard characteristics (for example soil types within the orchard and the value of fertiliser in the soil) and crop growth stages.

Mango trees grow through a series of growth events as shown in Figure 1. These events are influenced by various aspects such as the environment and management that impact productivity. The sequence of growth stages is (from harvest) shoot flush, root flush, shoot dormancy, pre-flowering, flowering, fruit development, root flush, and yield [8]. After harvest, the pruning activity will be carried out. This pruning is essential to produce new and robust young branches [2]. If pruning activities are not done, the old branches are likely not to bear fruit in the next season, having a stem (*Chlumentia transverse*) mango shoot borer in the branches, and produce small branches of not good quality [2][3].

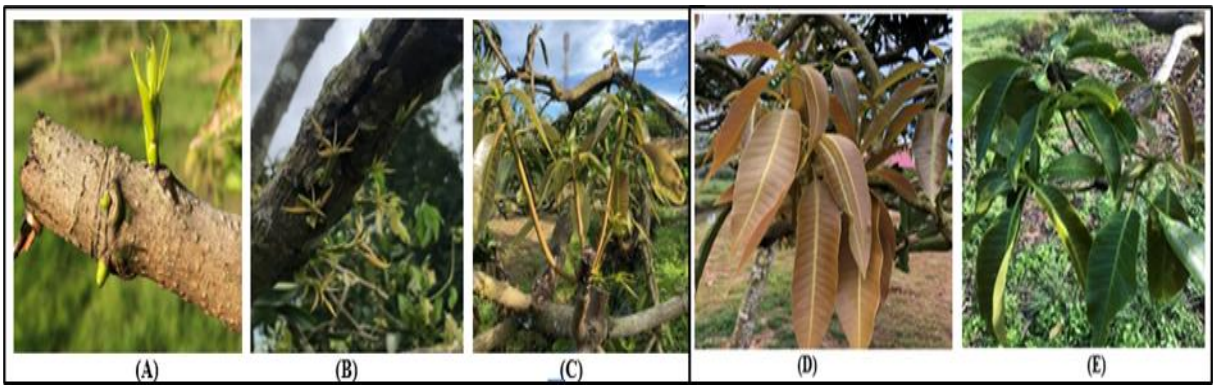

Figure 1. Vegetative shoot growth:

Vegetative Bud Emergence and Development stage (A), Elongating Green Leaf stage (B), Limp Red Leaf stage (C), Immature Green Leaf stage (D), and Mature Green Leaf stage (E).

3. MATERIALS AND METHODS

This sub-section illustrates and describes the methodology and material involved in this study.

3.1 Harumanis mango tree preparation

Pruning is a standard horticultural procedure that aims to regulate the size of fruit trees, improve light distribution within the canopy and orchard, and make cultivation and harvesting easier [2]. According to some studies, the yield of trimmed trees is greater [3], similar to or lower [4] than the unpruned trees. For a single species, such as the mango tree, the three instances might be documented [4]. The mango tree will be prepared through a pruning process with an open centre or vase shape technique. Pruning is done on the third week of May 2021 using the open centre technique or vase type (Figure 1). Considering the pruning to the current season's growth and the pruning of the previous season's growth, four plots were prepared for use in this experiment with the age of this tree has reached 9 years old.

3.2 Plant Material

This experiment was conducted during the 2021 season on nine-year-old Harumanis trees of a total of 24 trees. These trees were planted 30 x 30 feet apart (Figure 2), under surface irrigation conditions of a private farm Lot 1277, Guar Nangka, Perlis. The experiment was laid out with 24 treatments and three replications with a completely randomised design. Four levels of fertilisers (46% N, 46% P, 23% N 23%P, and 16%N 16%P 16%K) were applied alone and in combinations with *Urea Fertiliser* N46% / *Carbamide*, *Triple Super Phosphate* P46%, and *YARAMILA NPK* 16:16:16.

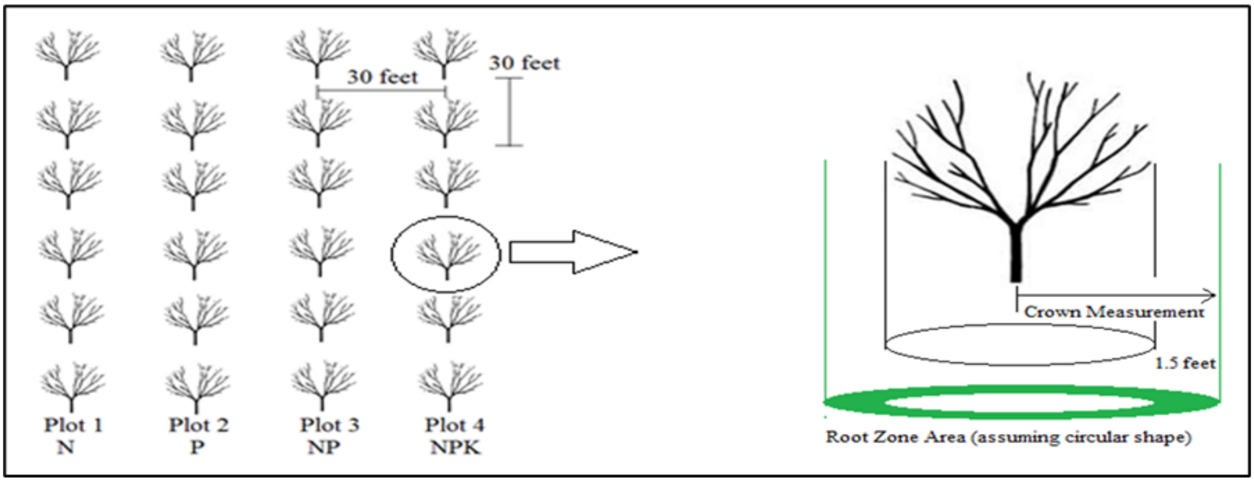

Figure 2: Trees were planted at a private farm Lot 1277, Guar Nangka, Perlis. Each plot is fertilised with different fertilisers. Crown measurement was taken from the middle trunk premier to the last branch with +1.5 feet.

The plants were fertilised in a certain amount based on the radius of the crown of the mango trees after pruning. Therefore, the measurements were taken with an average of 8.5 feet (radius). The step to calculate the amount of fertiliser is shown below:

Step 1:
Calculate root zone area (assuming circular shape).

$$Root\ Zone\ Area = \pi \times (r)^2 \tag{1}$$

Step 2:
Calculate the amount of fertiliser required for 1000 sqft.

$$Fertiliser\ Required = (Total\ kg.N\ x\ 100\%)\ /\ \%\ N\ in\ bag \tag{2}$$

Step 3:
Calculate the amount of fertiliser to be applied over the root area.

$$Fetiliser\ Apply = (Root\ area\ ft2\ /\ 1000sqft\ )\ x\ kg\ fertiliser\ per\ 1000\ sqft \tag{3}$$

The plant was fertilised with the required amount (Table 1) according to the tree's crown size. A1 to A6 trees received 46% nitrogen (511gram), B1 to B6 trees received 46% phosphorous (511gram), C1 to C6 trees received 23% nitrogen (255gram) and 23% phosphorous (255gram), and D1 to D6 trees received 16% nitrogen, 16% phosphorous, and 16% potassium (1460gram in total)[10][11][12]. After the two-week pruning procedure is completed, the trees were fertilised.

Table 1 Plant Fertilisation Amount

Tree Number	Fertiliser type	Amount	Crown size (sqft)
A1-A6	N (46%)	N: 511gram	235
B1-B6	P (46%)	P: 511gram	235
C1-C6	NP (23%)	N: 255gram P: 255gram	235
D1-D6	NPK (16%)	NPK: 1460gram	235

Shoot length was calculated using a measuring tape after the elongation of the green leaf began to come out. The number of green elongations was also calculated manually.

3.3 Measuring variables

Vegetative growth after pruning was monitored on each tree to assess the effect of different types of fertilisers. There are five phases involving vegetative growth, which are the Vegetative Bud Emergence and Development stage (VBE), Elongate Green Leaf (EGF) stage, Limp Red Leaf (LRL) stage, Immature Green Leaf (IGL) stage, and Mature Green Leaf (MGL) stage [9]. Each change in the phase will be recorded for analysis using the Multiple-Criteria Decision-Making (MCDM method.

The VBE starts appearing on the pruning branches 9 days after fertilisation. The development of VBE in visuals A and B was tracked weekly. The recorded data represent the complete VBE output for each pruning branch. On the 13th day after fertilisation [13], the VBE was measured for plots C and D. To achieve high growth of vegetative shoots, the LRL length (in inches) was also recorded. LRL's first care is quite important to produce flowers and fruit. Other qualities that are taken into consideration are the conversion period of IGL to MGL.

3.4 Data Analysis

MCDA methods are typically used to optimise decision-making while facing various choices with many conflicting and incongruous decision-making criteria. The technology is well-known for assessing multiple options with respect to different decision-making criteria to solve complex agriculture issues. Specific MCDA methods are popular with the Best Worst Technique (BWM) introduced by Dr. Jafar Rezaei (2015). The technique is used to compare a set of options against a group of decision criteria. The BWM is applied in this experiment to select the best and the worst values. Three criteria were used in a pairwise comparison of decision criteria that is done systematically. The requirements are (i) the total number of VBE, (ii) the length of LRF, and (iii) the time of MGL. When the decision-maker (DM) has identified the decision criteria, the DM selects two criteria: the best criterion and the worst criterion. The best measure is the one that plays the most significant part in the decision-making process, whereas the worst measure plays the opposite function.

Multiple decision -makers make the multi-criteria evaluation process in multiple periods. In each period, a set of alternatives that needed to be evaluated concerning the criteria was set. The following steps illustrate the organisation of this method:

<u>Step 1: Construct the decision matrix.</u>

This step produces decision matrix D of criteria and alternatives based on the information available regarding the problem. For example, if the number of other options is *m* and the number of measures is *n*, then a decision matrix having an order of *m* × *n* is represented as follows:

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

where x_{ij} denotes the performance measure of the i_{th} alternative in terms of the j_{th} criterion.
Step 2: Construct the normalised decision matrix.
In this step, the decision matrix is converted to a normalised decision matrix R. An element r_{ij} of the normalised decision matrix is calculated as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{kj}^2}} \quad (2)$$

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \quad (3)$$

where r_{ij} denotes the performance measure of the i_{th} alternative in terms of the j_{th} criterion.

Step 3: Construct the weighted normalised matrix.
The weighted normalised matrix is obtained by multiplying each column of the normalised decision matrix R with the associated criteria weight corresponding to that column. Hence, an element v_{ij} of the normalised matrix V is represented as follows:

$$V = RW \quad (4)$$

$$w = \begin{bmatrix} w_1 & 0 & 0 & 0 & \cdots & 0 \\ 0 & w_2 & 0 & 0 & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & 0 & \cdots & w_n \end{bmatrix} \quad (5)$$

$$\sum wi = 1 \quad (6)$$

$$v_{ij} = w_j \cdot r_{ij} \quad (7)$$

Step 4: Select beneficial or non-beneficial criteria.
For the benefit criteria, the decision maker wants to have the maximum value among the alternatives.

$$Beneficial = \frac{\min x_{ij}}{x_{ij}}; \quad Non-Beneficial = \frac{x_{ij}}{\max x_{ij}} \quad (8)$$

Step 5. Rank the Performance score.
Performance score as follows:

$$\sum v_{ij} \quad (9)$$
$$wi = 1 \quad (10)$$

4. RESULTS

Data were recorded for analysis to obtain the performance scores from the highest to the lowest. The recorded data include (i) the total number of VBE, (ii) the length of LRF, and (iii) the time of MGL.

4.1 Vegetative shoot growth

Good vegetative shoot growth is with a high VBE growth rate, long LRL branches, and a fast leaf conversion period to MGL. VBE will grow 14-21 days after pruning. The growth rate of VGE can be seen by the difference in the fertiliser elements given. Each branch that has been pruned can produce 5-9 units of VBE and change to the EGL stage. Fertilising the NP element and NPK element makes 6-7 units of VBE on each branch. This situation is different when applying element N and element P fertiliser with a growth rate of VBE at a rate of 3- 5 units on each branch. The highest total VBE production was on the C2 tree, which produced 7 units per branch. Tree C2 received NP element fertiliser at a rate of 511 grams overall. Table 2 shows the vegetative shoot growth for the trees.

Table 2 Vegetative shoot growth for the trees.

Tree Number	Shoot Pruning	VBE	Average VBE	LRL (inch)	MGL (days)	Fertiliser
A1	364	1528	4.20	4 to 5	15	N - 46%
A2	225	1012	4.50	6 to 7	15	
A3	193	617	3.20	4 to 5	15	
A4	334	1369	4.10	5 to 5	15	
A5	179	859	4.80	6 to 5	15	
A6	68	265	3.90	6 to 7	15	
B1	197	886	4.50	6 to 7	15	P - 46%
B2	155	651	4.20	6 to 7	15	
B3	241	1036	4.30	6 to 7	15	
B4	133	465	3.50	6 to 7	15	
B5	126	428	3.40	6 to 7	15	
B6	83	315	3.80	7 to 8	15	
C1	61	402	6.59	5 to 7	13	N - 23% P - 23%
C2	108	745	6.90	5 to 7	13	
C3	48	307	6.40	6 to 7	13	
C4	70	462	6.60	7 to 8	13	
C5	163	1010	6.20	6 to 7	13	
C6	261	1618	6.20	6 to 7	13	
D1	91	556	6.11	6 to 8	18	N - 16% P - 16% K - 16%
D2	121	822	6.79	7 to 8	18	
D3	81	421	5.20	7 to 8	18	
D4	73	459	6.29	7 to 8	18	
D5	61	384	6.30	7 to 8	18	
D6	49	308	6.29	6 to 8	18	
Min	48	265	3.20	4	13	
Max	364	1618	6.90	8	18	

The LRL stage growth is also considered because the long LRL will strengthen the branches to support the fruit's weight and produce good flowers. NPK and NP element fertilisers showed that the LRL length has reached the desired rate of 7-8 inches (average). While the use of N and P element fertilisers only gives the length of LRF at the rate of 4-6 inches. The change from LRL to MGL is recorded to determine the period taken in the phase change process. The change from LRL to MGL is calculated according to the number of days. The fastest rate of change is NP element fertiliser, which requires 13 days. N and P element fertilisers require 15 days for this conversion period while NPK essential fertilisers take the longest time of 18 days.

4.2 Multiple-Criterion Decision Analysis (MCDA)

Three data have been recorded for the analysis namely the total number of VBE (beneficial), the length of LRF (beneficial), and the time of MGL (non-beneficial). All three criteria are given the same weightage of 0.33. MCDA is used to obtain performance scores on each tree. The use of NP and NPK element fertilisers shows the best score. All of the trees with the use of NP and NPK fertilisers reached a target of more than 0.9. Applying N element fertiliser alone to the tree cannot provide enough nutrition to enable vegetative shoot growth to achieve the best level. While the use of P element fertiliser alone also did not reach a good grade. However, the use of P element fertiliser can provide consistent growth of vegetative shoot growth. Based on the result performance score in Table 3, results on the regrowth pattern after pruning when federalised with NPK fertiliser showed that the maximum percentage of total vegetative flush was 87.5% and the remaining 12.5% did not reach a satisfactory level according to the MCDA analysis. Tree numbers A1, A3, and A4 did not achieve an acceptable score (below 0.7). Failure of these three trees to reach a good level will delay the second stage of VBE.

Table 3 Results on the regrowth pattern after pruning when federalised with NPK fertiliser

Tree Number	VBE Normal	LRL Normal	Time MGl Normal	Performance Score
A1	0.20	0.13	0.29	0.627
A2	0.22	0.26	0.29	0.774
A3	0.15	0.13	0.29	0.580
A4	0.20	0.13	0.29	0.623
A5	0.23	0.26	0.28	0.770
A6	0.19	0.26	0.28	0.727
B1	0.22	0.26	0.29	0.774
B2	0.20	0.26	0.29	0.760
B3	0.21	0.26	0.29	0.764
B4	0.17	0.26	0.29	0.726
B5	0.16	0.26	0.29	0.721
B6	0.18	0.33	0.29	0.806
C1	0.32	0.33	0.28	0.921
C2	0.33	0.33	0.28	0.936
C3	0.31	0.33	0.29	0.931
C4	0.32	0.33	0.32	0.961
C5	0.30	0.33	0.34	0.966
C6	0.30	0.26	0.34	0.900
D1	0.29	0.33	0.29	0.917
D2	0.32	0.33	0.34	0.995
D3	0.25	0.33	0.32	0.894
D4	0.30	0.33	0.32	0.946
D5	0.30	0.33	0.32	0.947
D6	0.30	0.33	0.34	0.971

5. CONCLUSION

This experiment differentiates the ability of the fertiliser elements to enable vegetative shoot growth. Three main factors are considered namely the amount of VBE, LRL size, and the conversion period from LRL to MGL. All these elements are essential to determine the amount of Harumanis fruit production in the upcoming season. The four elements fertilisers of N, P, NP, and NPK have indicated different growth rates. The performance score from the MCDA analysis gives an initial picture that the use of NP and NPK elements is still the best. On the other hand, using single element fertilisers of N and P alone is so poor that the vegetative shoot growth rate does not reach the optimum rate.

References

[1] Singh, B.N., Dwivedi, P., Sarma, B.K. et al. *A novel function of N-signaling in plants with special reference to Trichoderma interaction influencing plant growth, nitrogen use efficiency, and cross talk with plant hormones*. 3 Biotech 9, 109 (2019).

[2] Oosthuyse, S.A. 1994. *Pruning of Sensation mango trees to maintain their size and effect uniform and later flowering.* S.A. Mango Growers Assoc. Yearbook 14:1-6. Pruning of Sensation Mango Trees to Maintain Their Size.

[3] Reddy, Y. T. N., & Kurian, R. M. (2008). *Cumulative and Residual Effects of Paclobutrazol on Growth, Yield and Fruit Quality of 'Alphonso' Mango*. Journal of Horticultural Sciences, 3(2), 119-122.

[4] Oosthuyse, S.A. 1997. *Tree size maintenance pruning of mango trees after harvest: Is cropping negatively affected or not?* S.A. Mango Growers Assoc. Yearbook 17:33-36.

[5] Oosthuyse, S.A. 1998. *Effect of fertilizer applications to the soil after harvest on leaf nutrient concentrations in mango.* S.A. Mango Growers Assoc. Yearbook 18:10-14.

[6] Rameswar, A. and M.A. Sultan, 1981. *Tentative leaf NPK standards in mango and nutritional survey of mango orchards in Andhra Pradesh.* National Symposium on Tropical and Sub-tropical Fruit Crops, Bangalore. pp 63. Catchpoole, D.W and Bally, I.S.E (1995)

[7] Haifa Group*. Controlled release fertilizer in precision agriculture.* from Knowledge Center & Community: http://www.haifagroup. com/knowledgecenter/articles/haifaarticles/ controlledreleasefertilizerinprecision agriculture.aspx. (2013)

[8] Renato de Mello Prado, *Phosphorus Effects in the Nutrition and Growth of Developing Mango Plants*, Journal of Plant Nutrition, 33:14, 2041-2049. (2010)

[9] Guzman-Estrada, C. *Relationship of macro and micronutrients content with some growth, production, dendrometric and climatic variables at the vegetative and reproductive phases of manila mango.* Acta Horticulturae, 509: 329–334. (2000)

[10] Sukthumrong, A., Boonkerd, N., Khumlert, R., Feungchan, S., Luksanawimol, P., Prasittikhet, J. and Sariyapan, O. *Plant nutrient and distribution under different fertilizer management in Nam Dok Mai mango.* Acta Horticulturae, 509: 307–314. (2000)

[11] A. E. A. Shaban, R. A. El-Motaium, S. H. Badawy & A. S. A. Ibrahim. *Response of mango tree nutritional status and biochemical constituents to boron and nitrogen fertilization*, Journal of Plant Nutrition, 42:20, 2784-2793. (2019)

[12] María C. Diez, Nelson W. Osorio & Flavio Moreno. *Effect of dose and type of fertilizer on flowering and fruiting of vanilla plants*, Journal of Plant Nutrition, 39:9, 1297-1310, (2016)

[13] Erel, R., A. Dag, A. Ben-Gal, A. Schwartz, and U. Yermiyahu. *Flowering and fruit set of olive trees in response to nitrogen, phosphorus, and potassium.* Journal of the American Society for Horticultural Science 133: 639–647. (2008)