Flush Intensity of Mango (*Mangifera indica* L. c.v. Carabao mango) Leaves as Affected by Different Flush Induction Protocol

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Abstract. The study was carried out to validate the effect of different flush induction protocol on carabao mango which was conducted in Alion, Mariveles, Bataan, Philippines with the following treatments: no intervention (T₁), pruning only (T₂), pruning with urea applied in soil (T₃), pruning with urea spray (T₄), pruning with irrigation (T₅), and complete flush induction protocol (T₆). Results revealed that providing water hasten the flush induction of mango. The complete flush induction protocol (T₆) significantly had the highest flushing percentage and the longest flushing duration. In terms of leaf produced per flush, pruning alone (T₂) and pruning with urea spray (T₄) equally produced the highest number of leaves per flush having 16 leaves. On the other hand, different flush induction protocols have no direct effect on flush and stem length, stem diameter, flush dry weight, and in the amount of nutrients in the flushes except for total amount of iron.

1. Introduction

Mango (*Mangifera indica*), the Philippine national fruit, not only gained its popularity because of the perfect blending of sweet and sour taste and its nutritional content but also because of its great economic importance. It is now considered as the third most important fruit crop in the country next to banana and pineapple [1]. Aside from eating it as a fruit or raw, it can be converted to many value-adding products that makes its local and international demand higher every now and then. However, despite of its demand and competitiveness in the world market, the mango industry has been confronted with major production challenges and issues, such as declining fruit yield and quality, occurrence of destructive pests and diseases, high cost of production, low profit margin, and unstable production. Apparently, these issues could affect the sustainability of the production supply, both in the domestic and international markets. Further, the production management and technology gaps generally affected the yield performance and productivity of mango in the past.

The mango production volume in the Philippines showed an increasing trend from 2012 to 2015 but decrease in 2016 and 2017. The peak production happened during the year 2015 with 740,239 metric tons with an average yield of 5.02 metric tons per hectare. The carabao mango production significantly decline in 2017 resulting to 598,713.5 metric tons, a reduction of roughly 141,526 metric tons (19%). In 2018, production also decline while there is only a slight increase in 2019.
According to PSA (2020) in their Oct-Dec 2019 quarterly report, the mango production in the Philippines was estimated at 27.78 thousand metric tons with slightly increased by 0.6% from its level in the same period a year ago [2]. The Zamboanga Peninsula had the highest production followed by Caraga and Northern Mindanao. Among the varieties of mango, carabao mango production accounted for 81.7% of the country’s total mango production having 22.69 thousand metric tons. In Central Luzon, there is also a decline in the production of carabao mangoes from 49,781 metric tons per hectare in 2011 down to 46,763 metric tons in 2012. It gradually increased in 2013 with 56,566 metric tons but decline again in 2014 (54,237 metric tons) and 2015 (52,698 metric tons) [3].

The trend in the mango volume of production shows an alarming trend in the entire mango industry; hence, proper interventions must be applied to increase the production supply. Efficient production of mango can be estimated not only on its flowering and fruiting performance but initially to its flushing intensity. Flushing which is defined as the production of new leaves is considered as one of the essential stages in the optimum growth and development of mango. Thus, mango trees need to flush as it will result to positive flowering and yield performance. There were already numerous flush induction techniques or combination of techniques and protocols that were applied in mango that believed to enhance the flushing performance of mango specifically in carabao mango variety. However, validation of the effectiveness of these various protocols and techniques must be closely determined and evaluated to develop an appropriate and effective flushing induction protocol for carabao mango trees which is applicable not only in the province of Bataan but also in the entire country.

The objectives of the study were to validate the effect of the different flush induction protocol on the flush intensity of carabao mango, and to identify the most appropriate and effective flush induction technique for carabao mango in the province.

2. Materials and methods

2.1. Experimental site and selection of mango trees

The study was conducted in Brgy. Alion, Mariveles, Bataan with an upland topography. It is located in the latitude of 21˚11’45” N and in the longitude of 72˚48’30” E with an estimated elevation of about 236.5 meters or 775.9 feet above mean sea level. In Mariveles, the wet season is overcast, the dry season is windy and partly cloudy, and it is hot and oppressive year-round. Over the course of the year, the temperature typically varies from 76°F to 91°F and is rarely below 73°F or above 94°F. Bataan in general has a distinct dry and wet season which is favorable for mango production. Its climate classification was Type I on Modified Corona’s climate classification while Am in Köppen-Geiger climate classification. The dry season starts in November to April while rainy season is from May to October. The temperature average from 27.5 °C with 31.0 °C as the highest while 24.0 °C lowest recorded temperature. The annual precipitation falls at 2852 mm of precipitation falls annually [4].

The mango trees used as experimental trees were selected based on the criteria set by the project team. The project team visited and validated the mango farms in the different municipalities in Bataan. Trees identified were grafted carabao mangoes within 25-30 years of age, with proper planting distance of at least 10 m x 10 m, with available source of irrigation, and the farmer had the willingness to follow and adopt the interventions. After the farm was validated, trees were immediately tagged, flush induction protocols were implemented and regular monitoring was done.

2.2. Experimental design and treatments

The study was a single factor experiment arranged in Completely Randomized Design (CRD) with six treatments and five replications. A total of 30 experimental trees were randomly selected in the mango orchard following the experimental design. The different treatments were as follows: Treatment 1 – no intervention (farmer’s conventional practice), Treatment 2 – pruning only, Treatment 3 – pruning and
2.3. Flushing parameters

The various data determined and measured during the study were the days from flush induction to flushing, duration of flushing, flushing percentage per tree, vegetative growth which includes the number of leaves per flush, length of flush, length of stem, stem diameter and the oven dry weight of flush (stem and leaves). The total amount of macro (nitrogen, phosphorus and potassium) and micro nutrients (zinc, copper, manganese and iron) in the flushes were also determined where 15-25 flush samples were collected for plant tissue analysis.

2.4. Data analysis

All the data were analysed using Analysis of Variance (ANOVA) for a single factor experiment arranged in Completely Randomized Design (CRD), and comparison among means was done using Least Significant Differences (LSD) at 5% level of significance.

The flushing performance of the experimental carabao mango trees in Alion, Mariveles, Bataan, Philippines was evaluated based on its phenology, growth behavior and presence of macro and micro nutrients in the leaves.

3. Results and discussion

3.1. First flush appearance, duration and percentage of flushing

As presented in Table 1, in terms of first flushing appearance, the treatment with pruning and irrigation (T5) and pruning with urea application, urea spray and irrigation (T6), significantly obtained the earliest day to produce new flushes which already produced flushes at 13 and 14 days after flush induction application, respectively, as compared with trees applied with pruning alone (T2) and pruning with urea application (T3). This finding indicate that the presence of water (irrigation) effectively hastens the flushing induction which reflects in the result obtained from T5 and T6 which both have irrigation supply of 400 L of water. It supports the study of Tahir, Ibrahim and Hamid (2003) that when mango trees are deficient with water, there will be reduction and delay in flush development, hence, when given enough water will promote growth and vegetative flushing [5]. It can also be observed that pruning with irrigation (T5) significantly flushed earlier as compared to trees with no interventions (T1). It can also be noted in the result that pruning with urea spray (T4) is just comparable with the result of all the other treatments in terms of days of first flushing appearance which means that the presence of nitrogen in the form of urea did not hasten the development of new flushes.

Table 1. Mango first flush appearance, duration and flushing percentage in response to different flush induction protocols.

| Treatment                             | Days from Flush Induction to First Flush Appearance | Duration of Flushing (days) | Flushing Percentage (%) |
|---------------------------------------|----------------------------------------------------|----------------------------|-------------------------|
| T1- No Intervention (Control)         | 17 \(^{ab}\)                                       | 23 \(^{b}\)                 | 26.00 \(^{c}\)           |
| T2- Pruning                          | 19 \(^{a}\)                                       | 23 \(^{b}\)                 | 32.40 \(^{bc}\)          |
| T3- Pruning and Urea Application     | 18 \(^{a}\)                                       | 24 \(^{b}\)                 | 39.00 \(^{b}\)           |
| T4- Pruning and Urea Spray           | 16 \(^{abc}\)                                      | 22 \(^{b}\)                 | 38.00 \(^{bc}\)          |
| T5- Pruning and Irrigation           | 13 \(^{c}\)                                       | 25 \(^{b}\)                 | 33.20 \(^{bc}\)          |
| T6- Pruning, Urea                    | 14 \(^{bc}\)                                      | 84 \(^{a}\)                 | 85.00 \(^{a}\)           |
In terms of flushing duration and flushing percentage, the complete flush induction protocol with pruning, urea application, urea spray and irrigation (T₆) significantly had the longest flushing duration (84 days) and the highest flushing percentage (85.00%) as compared with the rest of the treatments which shows that combination of all the flush induction protocol significantly prolong and improved the percentage of flushes produce per tree. This result is significant and an important input to improve the flushing performance of carabao mango trees since these flushes were the ones who will produce new flowers and fruits. It can also be noted that that the trees with no flush induction treatment also produce flushes which proved that carabao mango tree have the natural capacity for voluntary flushing as observed in T₁, however, when it comes to the intensity or percentage of flushing per tree, it can be observed that the trees with no treatments have much lower flushing percentage (26.00%) as compared to those trees applied with the flush induction techniques although it was just comparable with treatment with pruning only (T₂), pruning with urea spray (T₄), in and pruning with irrigation (T₅).

3.2. Vegetative growth behavior of flushes

In terms of leaf produced per flush presented in Table 2, pruning alone (T₂) and pruning with urea spray (T₄) equally produced the highest number of leaves per flush having 16 leaves which is significantly higher as compared with trees with no interventions (T₁) and to trees with pruning and urea applied in the soil (T₃). On the other hand, trees applied with pruning and irrigation (T₅) and pruning with urea application, urea spray and irrigation were just comparable with the rest of the treatments in terms of leaf production.

Based on the data obtained from the experiment, in terms of flush length, stem length, stem diameter and flush dry weight, there was no significant difference observed among treatments which shows that the different flushing protocols used in the study (pruning, urea application, urea spray, irrigation) has no direct effect on the vegetative growth behavior of flushes.

Table 2. Vegetative growth behavior of flushes in response to different flush induction protocols.

| Treatment                                | Leaf Number | Flush Length (cm) | Stem Length (cm) | Stem Diameter (mm) | Flush Dry Weight (g) |
|------------------------------------------|-------------|-------------------|------------------|-------------------|---------------------|
| T₁-No intervention (Control)             | 12 b        | 44.09             | 16.17            | 4.77              | 14.49               |
| T₂-Pruning                               | 16 a        | 42.75             | 17.88            | 5.79              | 17.26               |
| T₃-Pruning and Urea Application          | 11 b        | 40.20             | 14.68            | 5.06              | 11.39               |
| T₄-Pruning and Urea Spray                | 16 a        | 44.04             | 18.18            | 5.39              | 19.55               |
| T₅-Pruning and Irrigation                | 13 ab       | 43.34             | 18.14            | 6.23              | 18.62               |
| T₆-Pruning, Urea Application, Urea Spray | 14 ab       | 41.58             | 16.92            | 5.62              | 14.10               |

Means with the same letter are not significantly different.
Table 3. Macronutrients and micronutrients present in mango trees in response to different flush induction protocols.

| Treatment                                    | Macronutrients | Micronutrients |
|----------------------------------------------|----------------|----------------|
|                                             | Total Nitrogen (N), % | Total Phosphorus (P), % | Total Potassium (K), % | Total Zinc (Zn), ppm | Total Copper (Cu), ppm | Total Manganese (Mn), ppm | Total Iron (Fe), ppm |
| T<sub>1</sub>-No intervention (Control)     | 1.35           | 0.0800         | 0.7020         | 21.68             | 14.86            | 500.09                  | 290.50           |
| T<sub>2</sub>-Pruning                        | 1.32           | 0.0800         | 0.7020         | 19.40             | 13.24            | 430.63                  | 169.16           |
| T<sub>3</sub>-Pruning and Urea Application  | 1.48           | 0.0780         | 0.7080         | 21.72             | 14.70            | 431.33                  | 192.96           |
| T<sub>4</sub>-Pruning and Urea Spray         | 1.36           | 0.0800         | 0.7500         | 20.72             | 12.59            | 455.70                  | 237.72           |
| T<sub>5</sub>-Pruning and Irrigation         | 1.42           | 0.0800         | 0.6720         | 22.07             | 12.85            | 462.82                  | 192.02           |
| T<sub>6</sub>-Pruning, Urea Application, Urea Spray and Irrigation | 1.39           | 0.0780         | 0.6640         | 36.25             | 11.68            | 450.99                  | 197.74           |

Means with the same letter are not significantly different.

3.3. Plant tissue analysis

Based on the result of nutrient analysis for flush samples presented in Table 3, the presence of macro nutrients (N, P, K) in the matured flushes were not significantly different among treatments even in those treatments applied with urea in soil and sprayed in the leaf. It can be noted that the experimental area naturally has an efficient amount of endogenous nitrogen, phosphorus and potassium which is evident even in the treatments with no application of urea fertilizer. This result shows that application of the different flush induction protocol (pruning, urea application, urea spray and irrigation) has no significant effect on the amount of macro nutrient present in the flushes. This is possibly due to regular application of nitrogen and complete fertilizer by the farmer co-operator every cropping season.

In terms of trace elements, there were also no significant difference observed among treatments in terms of total zinc (Zn), total copper (Cu) and total manganese (Mn) present in the flushes, on the other hand, in terms of total iron (Fe), it can be observed in the data that trees with no intervention (T<sub>1</sub>) significantly had the highest amount of iron in the flushes (290.50 ppm) as compared with trees with pruning alone (T<sub>2</sub>), pruning with urea application (T<sub>3</sub>), pruning with irrigation (T<sub>5</sub>) and pruning with urea application, urea spray and irrigation (T<sub>6</sub>). On the other hand, the amount of iron in trees with no intervention (T<sub>1</sub>) is just comparable with the amount of total iron in trees with pruning and urea spray (T<sub>6</sub>).

In plants, micronutrients are required for different physiological and metabolic processes, and their deficiency affects a number of processes including hindered plant growth, productivity, and quality [6], [7], [8], [9]. In enzymatic activities, micronutrients act as a cofactor and take part in a number of oxidation-reduction reactions [10]. The key role of micronutrients is in respiration and photosynthesis [11]. Zinc plays a role in enzymatic activities and confers high sugar contents to fruits [12], [13]. Manganese (Mn) application is crucial for plant yield and relative growth, photosynthesis, and the net assimilation rate of plants [14]. On the other hand, iron (Fe) affects the yield, chlorophyll contents, fruit quality, and mineral nutrients in a number of fruit trees [15], [8].
4. Conclusion
The result of the study proved that carabao mango trees have the natural capacity for voluntary production of flushes after harvest even without applying any interventions; however, the flushing performance varies depending on the protocol applied. It can be observed in the result that appearance of first flushes hasten when performed pruning with irrigation as recorded in T5 and T6 which produces flush at 13 and 14 days after the intervention application, respectively. Meanwhile, in flushing duration and percentage of flushing per tree, the complete flush induction protocol (with pruning, urea application, urea spray and irrigation) significantly had the longest duration and the highest flushing percentage as compared with the rest of the treatments which shows that combination of all the flush induction protocol significantly improved the percentage of flushes produce per tree.

In terms of leaf produced per flush, pruning alone (T2) and pruning with urea spray (T4) equally produced the highest number of leaves per flush having 16 leaves which is significantly higher as compared with trees with no interventions (T1) and to trees with pruning and urea applied in the soil (T3). In total iron (Fe), trees with no intervention (T1) significantly had the highest amount of iron in the flushes as compared with trees with pruning alone (T2), pruning with urea application (T3), pruning with irrigation (T5) and pruning with urea application, urea spray and irrigation (T6). On the other hand, the amount of iron in trees with no intervention (T1) is just comparable with the amount of total iron in trees with pruning and urea spray (T4).

Based on the data obtained from the experiment, the different flush induction protocols applied in the study (pruning, urea application, urea spray, irrigation) has no direct effect on flush duration, flush length, stem length, stem diameter, flush dry weight, nitrogen, phosphorus, potassium, zinc, copper, and manganese content of the new flushes.

5. Recommendations
Based on the result of the initial study, it is therefore recommended to apply the complete flush induction protocol for carabao mango (pruning, urea and irrigation) for early flush development, longest flushing duration and high percentage of flushing for these are the important indicators of flowering capacity of a mango tree. On the other hand, it is still recommended to conduct further study on the effect of applying different flush induction protocol in the growth and yield of carabao mango tree in other municipalities of Bataan and continue the monitoring of the study up to its flowering and harvest stage.

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