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Effects of Different Scions on Macronutrient Resorption of Mango Kensington Pride Rootstock

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ABSTRACT

Nutrient resorption is a process of nutrient remobilization from senesced organs to living tissues inside a plant. Since the Northern Territory (NT) has relatively poor soil conditions and a limited supply of plant nutrients, it is crucial to determine suitable scions for efficient macronutrient resorption in the Kensington Pride (KP) mango rootstock. The scions used in this study were NMBP 1201 (T1), NMBP 1243 (T2), NMBP 4069 (T3), B74 (T4), and KP (T5). The experiment occurred in a randomized, complete block design with five treatments and five replicates. The results showed that grafting the B74 scion onto the KP rootstock resulted in trees with reduced canopy area (65.76 ± 4.39b) and volume (48.43 ± 4.92b), indicating its suitability for narrow-planting distance to produce more mangoes in a smaller area. Grafting the B74 scion onto the KP resulted in a larger leaf area (6.52 ± 1.36), ultimately increasing nutrient resorption efficiency, which is beneficial in nutrient-deficient soils like in the NT. NMBP 4069 scions grafted onto the KP rootstock had a larger canopy area (87.47 ± 5.37a) and canopy volume (72.23 ± 6.21a). These trees need more space to grow and have lower nutrient resorption efficiency, owing to their smaller leaf area. The scions NMBP 1201 and NMBP 1243 displayed comparable growth metrics and nutrient resorption efficiency when grafted onto the KP. Scions of the B74 can be highly suitable to withstand diverse environmental conditions, optimize nutrient use, and increase fruit yield on a commercial level.

Introduction

Soil nutrient availability limits plant performance worldwide. Soil nutrient limitations arise from several factors, such as climate, soil age, and parent material (Drenovsky et al., 2019). Nutrient resorption is an essential method for maintaining plant nutrients. It is a process of nutrient remobilization from senesced organs to living tissues inside a plant. It is an internally important mechanism that allows plants to avoid nutrient loss and extraction from older leaves and enables them to utilize them again (Suttle, 2022). Nutrient resorption finds expression in two ways: resorption efficiency (RE), i.e., the amount of green leaf nutrients extracted before senescence of the leaves, and resorption proficiency (RP), i.e., the amount of nutrient concentration in senesced leaves. Nutrient resorption proficiency can describe leaf nutrient content, which diminishes during senescence. Various studies have explained that resorption efficiency and

proficiency are ecologically significant processes. Nutrient resorption is physiologically essential in nutrient recycling, which helps in nutrient conservation. It impacts various ecosystem processes by supporting plants to reuse nutrients, reduce nutrient losses, and make plants less dependent on soil nutrients (Prieto et al., 2018). It also entails significant ecological consequences, such as competition between plants for nutrients, nutrient uptake, and productivity. It also contributes to biogeochemical cycling by impacting litter-fall quality, thus affecting litter decomposition and soil nutrient availability (Aerts, 1996; Prieto and Querejeta, 2020).

Mango trees need nutrients for growth, production, and fruit quality. The most essential macro-nutrients required by mango trees are nitrogen (N), phosphorus (P), potassium (K), and secondary macro-nutrients like calcium (Ca), magnesium (Mg), and sulfur (S). Also, the availability of micronutrients like boron (B), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) is essential to the health of the plant. An ideal ratio of these nutrients, supplied at the correct time, results in increased mango production on a sustainable basis and guarantees fruit quality (Torres et al., 2002; Cvelbar Weber et al., 2021; Silber et al., 2022).

Nutrients play a major role in plant growth at all stages of the mango tree. Nitrogen is important for vigor, vegetative growth, and physiological development in mango trees. Phosphorus plays an important role in cell division, development, and the production of sugar-phosphate molecules. Plants need K for resistance to pathogens and insect pests, controlling water uptake, and improving the quality of mango fruit (Bhatla et al., 2018). Calcium provides membrane stability and supports cell walls. It also assists in regrowth and new flushes directly after harvest to keep the fruit firm. Magnesium is a fundamental nutrient for chlorophyll, and sulfur is essential for enzyme and protein synthesis (Barker and Pilbeam, 2015; Pessarakli, 2021). Iron and Mn assist in chlorophyll formation (Suman et al., 2017), while Zn contributes to protein synthesis in mango plants, controlling water movements within the plant (Alloway, 2008). Furthermore, B facilitates mango cell division by ensuring pollination and fruit development. Cu aids in photosynthesis because it lignifies cell walls to ensure the smooth transport of carbohydrates and water (Suman et al., 2017).

Mangoes are predominantly grown in the Northern Territory and Queensland and, when combined, produce approximately 95% of the total national crop in Australia. Western Australia, New South Wales, Victoria, and South Australia also have mango orchards. Due to climatic conditions and irregular crop bearing, the total volume of fruit marketed varies from season to season. Global mango yield over the last three years has been approximately 70,000-75,000 tons on average. Gross production value (GVP) by farm gate is ca. $185 million per annum (AMIA, 2022). Mangoes are the largest horticultural commodity in the Territory. The industry contributes over $128 million to the economy, and during harvest, it employs 3500 workers. Mango farmers in the Territory produce 52% of Australia's crop and supply the first crop of the season to Australian consumers (NT Farmers, 2023). The Darwin region accounts for 24% of Australian production, almost all from Litchfield (Bristow et al., 2017).

Trees either resorb or absorb soil nutrients from their own senesced tissues, and this process includes various cost-input mechanisms (Aerts and Chapin, 1999). If the green leaves have lower nutrients, the senescence leaves would also have lower nutrients, and hence it would result in higher resorption in a drier and poorer nutrient situation (Aerts and Chapin, 1999; Wang J. et al., 2022). According to Vergutz et al. (2012) and Prieto et al. (2018), NRP conversely depends on soil nutrient status.

Plants grown in nutrient-poor soil conditions are expected to have higher resorption efficiency and proficiency (Li et al., 2013; Wang et al., 2021). Soil nutrient accessibility largely controls leaf nutrient resorption efficiency (Zhao et al., 2017). Trees grown in nutrient-deprived soil conditions have greater resorption efficiency than those in nutrient-rich soil conditions (Killingbeck, 1996; Wright and Westoby, 2003; Rumman et al., 2018). The current research considers the interaction between rootstock and scion on macro- and micronutrient resorption rates in mango trees. The relationship between the rootstock and scion is bidirectional through the xylem and phloem and incorporates water, supplements, hormones, metabolites, peptides, small organic molecules, and nucleic acids (Kawaguchi et al., 2022). Some work has been done in the past to standardize the rootstock for different varieties of the scion, including the use of polyembryonic varieties for vigor management, drought resistance, and better results in terms of mango fruit quality and quantity (Nimbolkar et al., 2016). Though there is clear evidence that rootstocks can provide better yield and yield efficiency in different vegetables and fruits, there is insufficient information on how different scions can affect the nutrient resorption of mango rootstock. Thus, this research aimed to determine the effects of five different scions on macro-nutrient resorption

when grafted onto a KP scion and to estimate the best combination of scion and rootstock for nutrient resorption in the KP mango variety.

Materials and Methods

Location and sample collection

Leaf samples were collected from mango trees at Katherine Research Station (KRS), Darwin, NT, Australia (latitude 14.4830 S, longitude 132.239000 E). The station is located near the Katherine River below the "Top End," 320 km southeast of Darwin. Katherine is characterized by high temperatures, ranging from 29 to 35 °C, with a semiarid tropical climate and an extreme wet season (average 972 mm year-1) from December to February, followed by a distinct dry period in almost all the continuing months (Smith et al., 2008; Hickey, 2016). The soil type found at the Katherine Research Station was Tippera Ferric, Petroferric, Red Kandosol (loamy, Typic Alfisol) with free drainage throughout the area. The soil had a pH level of 8 and an electrical conductivity of less than 0.05 dS m-1 (Smith et al., 2008).

Treatments and experimental design

We analyzed the effects on macro- and micronutrient resorption of five samples from the trees, grafted using five different varieties of scions on the KP rootstock. We used the following scions: NMBP 1201 (T1), NMBP 1243 (T2), NMBP 4069 (T3), B74 (T4), and KP (T5). Samples were from the trees where the experiment occurred in a randomized complete block design with five treatments and five replicates. We collected 20 green and 20 yellow leaves from each treatment for the sample processing.

Leaf sampling and analysis

Twenty mature green leaf samples were collected from the top, bottom, east, and west tree sides and put into labeled paper bags. Similarly, twenty senesced leaves were collected by touching the yellow leaves attached to a branch. We collected the senesced leaves from the same branches as the green leaves. Fifty bulk leaf samples were obtained from the mango orchard, with five treatments and five replications per treatment for both green and yellow leaf samples.

The samples were stored in an ice chest containing coolants (ice blocks) during transport to Berrimah Research Farm (BRF), Darwin. At the BRF laboratory, the leaves underwent manual cleaning and gently rubbing between the thumb and forefinger, rinsing them with running tap water after mildly soaking them in a detergent solution. The leaves were thoroughly washed with distilled water and dried using clean tissue paper to remove the impurities. The petioles from every leaf were cut off to allow for easy measurement of the leaf surface area. The number of leaves per bulk leaf sample was recorded. A chlorophyll meter (SPAD 502) determined an average soil plant analysis development (SPAD) per bulk leaf sample. New paper bags were prepared and tagged to match the references on the prior bags. This was done to ensure that, following washing and measurement, each bulk leaf sample was moved to its corresponding new paper bag.

The leaves were later dehydrated in a forced-air circulation oven at a temperature of 70 °C until a constant weight was achieved. We used an electronic balance to determine the dry weight of all the bulk samples. After taking out the samples from the oven, we first crumbled the bulk leaves in the paper bag and immediately crushed and ground the leaves, as they were easier to crush when still warm. We thoroughly washed the entire mill, including its lid, with a diluted solution of Decon90 before transferring it into the chromed ring mill bowl. The bowl was cleaned twice with tap water, rinsed with distilled water, and dried with clean tissues. The cleaning procedure was finalized by applying ethanol to the grinder and wiping it with tissue paper. The chrome-plated ring mill bowl was securely sealed with its lid, carefully inserted into the ring mill, and tightly fastened to prevent movements or detachment. We programmed the mill to operate for 1.5 min, ensuring the crushed leaves were ground into small, uniform particles. The grinder was removed, and finely ground bulk leaf samples were transferred into a clean container. Each of the ground bulk samples was placed into separate containers, with 4 g of each sample sent to the CSBP Soil and Plant Analysis Lab (https://csbp-fertilisers.com.au/services/lab) for analysis of N, P, K, Ca, Mg, and S content.

Data collection

Leaf area (LA)

The leaf samples were measured using a digital leaf area meter. The leaves were placed and distributed on a plastic platform connected to the conveyor of the digital leaf area meter. The meter was activated while the reading was reset. The conveyor belt propelled the plastic, transporting the leaves inside the machine. As the leaves traveled past a head scanner, their leaf area was immediately measured. Following the scanning process, the leaves exited the machine at the opposite end. We sequentially placed additional leaves on the platform until we measured all the

leaves from a specific bulk sample. The meter instantly calculated the total area of the bulk leaf sample. Once the meter readings were reset, the process was repeated for the next bulk leaf sample, according to Narwal et al. (2007).

Chlorophyll content

Chlorophyll content was measured using SPAD-502. SPAD-502 m (meter) is an elective technique for estimating comparative leaf chlorophyll content, and it overcomes all the weaknesses. It is a convenient, hand-held gadget that utilizes two light-discharging diodes, contains a silicon photodiode sensor, and estimates leaf transmission in the red (650 nm; the wavelength estimating) and infrared (940 nm, a reference wavelength to modify for vague contrasts amid tests) areas of the electromagnetic range. These transmissions go through the gadget to determine a comparative SPAD meter charge (generally between 0.0 and 50.0), corresponding to the measure of chlorophyll in the taste (Uddling et al., 2007). The SPAD meter has broad applications in research purposes and agricultural use.

Nutrient resorption efficiency (NRE)

Nutrient concentrations in green and yellow leaves were utilized to compute NRE on a bulk basis (Killingbeck, 1996). Nutrient resorption efficiency can be determined by the supply of nutrients into mobile and unsolvable chemical portions, leaf chemical synthesis, carbohydrate fluidity, and environmental circumstances (Eckstein et al., 1999). González et al. (2015) computed it using the following formula.

$$NRE = \left(\frac{Ngreen - Nyellow}{Ngreen}\right) \times 100$$

Where N-green and N-yellow are the nutrient absorption in green leaves and yellow leaves, respectively.

Nutrient resorption proficiency (NRP)

The N, P, K, Ca, Mg, and S contents of the yellow leaf samples generated the NRP value. Macronutrient concentrations in the yellow leaf were used as an indicator of the NRP (Killingbeck, 1996).

Nutrient content of green leaf (Ngreen)

Ngreen was obtained from the results of the Ca, Mg, S, N, P, K, analysis of the green leaf samples.

Nutrient content of yellow leaf (Nyellow)

Nyellow was obtained from the results of the Ca, Mg, S, N, P, and K analysis of the yellow leaf samples. The growth parameters of the experimental trees were determined at KRS. The parameters analyzed included the tree height, the trunk height (measured as the distance from the ground to the first branch), and the diameter of the tree canopy in both the north-south (NS) and east-west (EW) directions. The level staff and tape measure determined the structural parameters.

Tree and crown height (m)

Tree height was measured using level staff on the field after leaf sample collection. Crown height was calculated using the following formula:

$$Tree\ height - Trunk\ height$$

Canopy area (m²)

The canopy area was calculated using the following formula:

$$Canopy\ Area = (2 \times (crown\ height\ x\ canopy\ diameter\ EW)) + (2 \times (crown\ height\ x\ canopy\ diameter\ \ NS)) + (canopy\ diameter\ EW\ x\ canopy\ diameter\ NS)$$

Where, NS = north-south
EW = east-west

Canopy volume (m³)

Canopy volume was calculated using the following formula:

$$Length \times Width \times Height\ of\ the\ tree$$

Leaf dry weight (LDW) (kg m⁻²)

$$LDW = \frac{dry\ weight}{Number\ of\ leaves}$$

Leaf area (LA) (m2)

The following formula resulted in leaf area.

$$LA = \frac{Leaf\ area}{Number\ of\ leaves}$$

Dry weight leaf area (DWLA)

and was calculated using the following formula.

$$DWLA = \frac{Weight\ per\ leaf}{Area\ per\ leaf's}$$

Statistical analysis

Statistical analysis involved using the Statistical Tool for Agriculture Research (STAR, version 4.1)

of the International Rice Research Institute (IRRI). Treatment effects were determined by the analysis of variance (ANOVA), and mean values were compared using the least significant difference (LSD) ($p \leq 0.05$). Data were subjected to normality tests using the Shapiro-Wilk method, and homogeneity of the variance tests followed the Bartlett method (Moder, 2010).

Results

Effects of different scions with the KP rootstock on growth

Table 1 shows significant variations in the canopy area ($p = 0.04$) and canopy volume ($p = 0.03$) among scions grafted onto the KP rootstock. However, tree height ranged from 3.93 ± 0.13 to 4.66 ± 0.13 m and was comparable ($p = 0.11$) among scions. Among the varieties, the NMBP 4069 scions grafted onto the KP rootstock had a higher canopy area and canopy volume than the B74 scions, but they were comparable to those of NMBP 1201, NMBP 1243, and the control tree (KP). The B74 scion had the smallest canopy area (65.67 m^2) and volume (48.43 m^3), suggesting that grafting the B74 scion onto the KP decreased the tree canopy area and canopy volume.

Table 1. Mean ± SE of tree height, canopy area, and canopy volume as influenced by the grafting NMBP 1201, NMBP 1243, NMBP 4069, B74 and KP scions onto the KP rootstock.

Scions	Tree height (m)	Canopy area (m^2)	Canopy volume (m^3)
NMBP 1201	4.41 ± 0.09	82.13 ± 2.13^{ab}	66.98 ± 2.51^{a}
NMBP 1243	4.11 ± 0.24	72.95 ± 7.14^{ab}	56.68 ± 7.24^{ab}
NMBP 4069	4.66 ± 0.13	87.47 ± 5.37^{a}	72.23 ± 6.21^{a}
B74	3.93 ± 0.13	65.76 ± 4.39^{b}	48.43 ± 4.92^{b}
KP	4.55 ± 0.29	88.30 ± 5.19^{a}	73.76 ± 5.42^{a}

Means followed by common letters are not significantly different using LSD 0.05. NMBP: National Mango Breeding Program, B74: Calypso®, KP: Kensington Pride.

Effects of different scions with KP rootstock on leaf sample colour

Leaf SPAD value ($p = 0.01$) and leaf dry weight ($p = 0.03$) varied significantly among scions that were grafted onto KP rootstock (Table 2). However, leaf area ($p = 0.02$) and specific leaf area ($p = 0.04$) were comparable among scions. Among the varieties, NMBP 4069 and B74 scions grafted onto the KP rootstock had a higher leaf SPAD value than NMBP 1243 and the control tree (KP) but were comparable to NMBP 1201. The B74 scion had a wider leaf area and higher leaf dry weight than NMBP 1201, NMBP 1243, NMBP 4069, and the control tree. However, the NMBP 1201, NMBP 1243, NMBP 4069, and the control tree were comparable in leaf area and leaf dry weight. The B74 scion had a higher specific leaf area than NMBP 4069 and KP, but was comparable with that of NMBP 1201 and NMBP 1243. The higher leaf SPAD value (45.46), wider leaf area (10.06 m^2), higher leaf dry weight (1.73 mg), and higher specific leaf area (0.17 m^2) of B74 indicated that grafting it onto the KP made the trees grow larger leaf areas. According to Seemann et al. (1987), photosynthetic rate and nitrogen capacity correlate with chlorophyll content in plant leaves.

Effects of different scions with KP rootstock on nutrient concentration

The phosphorous content ($p = 0.04$), K content ($p = 0.00$), Mg content ($p = 0.0$), and S content ($p = 0.03$) varied significantly among scions that were grafted onto the KP rootstock (Table 3). However, the N content ($p = 0.17$) and Ca content ($p = 0.37$) were comparable among scions. Among the varieties, the NMBP 4069 scion grafted onto the KP rootstock had a higher P content than other varieties. However, P levels in the NMBP 1201, NMBP 1243, and B74 scions grafted onto the KP rootstock were similar to each other. The K contents in NMBP 1201 and NMBP 1243 scions grafted onto the KP rootstock were similar to each other, but the NMBP 4069 scion had the highest K content among all scions. The magnesium contents of NMBP 1201 and NMBP 1243 scions grafted onto the KP were comparable; however, the magnesium content varied significantly among other scions. The sulfur content of the B74 scion grafted onto the KP was comparable to that of the NMBP 1201, NMBP 1243, and NMBP 4069.

Table 2. Mean ± SE of SPAD value, leaf dry weight, leaf area and specific leaf area of green and yellow leaves influenced by grafting NMBP 1201, NMBP 1243, NMBP 4069, B74 and KP scions onto the KP rootstock.

Scions	Leaf SPAD value	Leaf area (m^2)	Leaf dry weight (mg)	Specific leaf area (m^2)
NMBP 1201	42.78 ±1.54^{ab}	6.04 ± 1.49	6.83 ± 0.59^{b}	3.66 ± 0.32
NMBP 1243	38.08 ± 1.51^{b}	4.68 ± 0.81	7.55 ± 0.56^{b}	4.60 ± 0.33
NMBP 4069	44.78 ± 1.45^{a}	6.78 ± 0.64	6.94 ± 0.49^{b}	3.94 ± 0.28
B74	45.46 ± 1.31^{a}	6.52 ± 1.36	10.06 ± 1.11^{a}	5.80 ± 0.70
KP	38.66 ± 2.08^{b}	4.06 ± 1.04	7.02 ± 0.12^{b}	5.74 ± 1.13

Means followed by common letters are not significantly different using LSD 0.05. NMBP: National Mango Breeding Program, B74: Calypso®, KP: Kensington Pride, SPAD: Soil Plant Analysis Development.

Table 3. Mean ± SE concentrations of macro-nutrients of mango as influenced by grafting NMBP 1201, NMBP 1243, NMBP 4069, B74, and KP scions onto the KP rootstock.

Scions	Nutrient concentration(mg kg^{-1})					
	N	P	K	Ca	Mg	S
NMBP 1201	0.93 ± 0.03	0.07 ± 0.01^{b}	1.04 ± 0.08^{c}	2.91 ± 0.19	0.18 ± 0.01^{a}	0.09 ± 0.00^{bc}
NMBP 1243	0.87 ± 0.05	0.05 ± 0.01^{b}	0.81 ± 0.04^{c}	3.04 ± 0.21	0.17 ± 0.02^{a}	0.08 ± 0.00^{c}
NMBP 4069	0.95 ± 0.02	0.05 ± 0.00^{a}	0.49 ± 0.02^{a}	3.07 ± 0.18	0.19 ± 0.02^{b}	0.09 ± 0.00^{ab}
B74	0.85 ± 0.01	0.04 ± 0.00^{b}	0.54 ± 0.02^{b}	3.48 ± 0.09	0.27 ± 0.01^{b}	0.08 ± 0.00^{abc}
KP	0.88 ± 0.05	0.05 ± 0.00^{b}	0.52 ± 0.04^{c}	3.10 ± 0.23	0.28 ± 0.04^{b}	0.07 ± 0.00^{a}

Means followed by common letters are not significantly different using LSD 0.05. NMBP: National Mango Breeding Program, B74: Calypso®, KP: Kensington Pride, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, S: Sulphur.

Effects of different scions with the KP rootstock on nutrient resorption proficiency

The phosphorous resorption proficiency (p = 0.01), KRP (p = 0.00), and MgRP (p = 0.00) showed considerable variations among scions grafted onto the KP rootstock (Table 4). However, the NRP (p = 0.12), CaRP (p = 0.07), and SRP (p = 0.25) were comparable among the scions. Among the varieties, the NMBP 4069 scion grafted onto the KP had a higher PRP than the NMBP 1201 scion and the control tree. However, it was comparable with that of the NMBP 1243 and B74 scions grafted onto the KP. NMBP 4069 scions grafted onto the KP also had a higher KRP compared to any other varieties. NMBP 1201 and NMBP 1243 scions grafted onto the KP had a comparable MgRP, which was significantly higher than those of other varieties. The B74 scion, when grafted onto the KP, had higher values of MgRP when compared to that of the NMBP 4069. However, it varied significantly with that of the NMBP 1201, NMBP 1243, and the control tree (KP).

Effects of different scions with KP rootstock on nutrient resorption efficiency

The phosphorous resorption efficiency (p = 0.02), CaRE (p = 0.02), and MgRE (p = 0.00) showed substantial variations among scions grafted onto the KP rootstock (Table 5). However, the NRE (p = 0.11), KRE (p = 0.25), and SRE (p = 0.31) were similar among the different scions. Among the varieties, the NMBP 1201 scion grafted onto the KP rootstock had a higher PRP than the NMBP 4069 and B74 scions, but was comparable to that of the NMBP 1243 scion. The calcium resorption efficiency was comparable among NMBP 1201, NMBP 4069, B74 scions, and the control tree. However, it varied significantly with NMBP 1243 scions compared to the other

varieties. The B74 scion, when grafted onto the KP, had higher MgRE than the NMBP 1201 and NMBP 1243 scions. However, it was comparable to the NMBP 4069 scion when grafted onto the KP.

Table 4. Mean ± SE nutrient resorption proficiency of macro-nutrients of mango as influenced by grafting NMBP 1201, NMBP 1243, NMBP 4069, B74, and KP scions onto the KP rootstock.

Scions	Nutrient resorption proficiency (%)					
	N	P	K	Ca	Mg	S
NMBP 1201	0.50 ± 0.01	0.03 ± 0.01^{b}	0.84 ± 0.01^{c}	3.72 ± 0.12	0.09 ± 0.01^{a}	0.07 ± 0.00
NMBP 1243	0.49 ± 0.01	0.02 ± 0.00^{ab}	0.65 ± 0.00^{c}	3.61 ± 0.22	0.05 ± 0.01^{a}	0.07 ± 0.00
NMBP 4069	0.47 ± 0.01	0.01 ± 0.00^{a}	0.34 ± 0.00^{a}	3.34 ± 0.15	0.12 ± 0.01^{bc}	0.07 ± 0.00
B74	0.46 ± 0.00	0.01 ± 0.00^{ab}	0.36± 0.00^{b}	4.12 ± 0.09	0.20 ± 0.01^{c}	0.06 ± 0.00
KP	0.47 ± 0.02	0.02 ± 0.00^{b}	0.33 ± 0.00^{c}	4.68 ± 0.63	0.20 ± 0.04^{b}	0.07 ± 0.01

Means followed by common letters are not significantly different using LSD 0.05. NMBP: National Mango Breeding Program, B74: Calypso®, KP: Kensington Pride, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, S: Sulphur.

Table 5. Mean ± SE nutrient resorption efficiency of macro-nutrients of mango as influenced by grafting NMBP 1201, NMBP 1243, NMBP 4069, B74, and KP scions onto the KP rootstock.

Scions	Nutrient resorption efficiency (%)					
	N	P	K	Ca	Mg	S
NMBP 1201	45.65 ± 1.42	57.91 ± 7.47^{ab}	18.21 ± 2.47	-29.33 ± 6.05^{a}	49.81 ± 4.45^{c}	17.78 ± 2.72
NMBP 1243	43.17 ± 2.79	55.76 ± 7.03^{bc}	18.77 ± 3.28	-20.67 ± 9.87^{b}	64.79 ± 7.36^{c}	18.33 ± 4.24
NMBP 4069	50.78 ± 1.89	80.00 ± .00^{c}	29.79 ± 4.53	-9.17 ± 2.40^{ab}	35.89 ± 2.13^{ab}	16.22 ± 5.04
B74	45.63 ± 0.95	76.00 ± .00^{c}	31.30 ± 5.79	-18.40 ± 3.15^{a}	25.45 ± 4.43^{a}	15.55 ± 6.67
KP	45.08 ± 3.16	61.43 ± .99^{a}	36.85 ± 11.78	-50.37 ± 14.15^{a}	30.50 ± 5.75^{bc}	5.00 ± 5.46

Means followed by common letters are not significantly different using LSD 0.05. NMBP: National Mango Breeding Program, B74: Calypso®, KP: Kensington Pride, N: Nitrogen, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, S: Sulphur.

Discussion

The annual growth cycle of mango is linked to its reproductive cycle and growth stages, which are influenced by hormonal factors. Differences in the levels of inhibitory regulators and growth promoters may be crucial factors that influence the vegetative growth of certain mango plants. According to Elfving in 1984, an increase in cytokinin hormones compared to auxin hormones in plants promotes vegetative growth, but growth is suppressed when auxin hormones are dominant. A rise in levels of auxins may suggest their involvement in suppressing dormant bud formation, thus affecting the vegetative growth of plants (Müller and Leyser, 2011). Another reason may be due to low vigor resulting from hormonal presence affecting the plants (Rosecrance et al., 1998). Reduced vigor can lead to early flowering, an increased number of flowers, and early fruit production, whereas high vigor may result in excessive vegetative growth and low fruit yield (Koepke and Dhingra, 2013). Growth in B74 appeared to be focused more on leaf expansion, flowering, and fruiting, which may result in low canopy area and canopy volume. However, the growth in scions such as NMBP 4069 and NMBP 1201 appeared to be concentrated on increasing canopy size and

volume, potentially impacting fruit production.

The leaf area of a plant plays a significant role in capturing and using light, which impacts plant growth and canopy area. One significant method by which plants boost photosynthesis is through leaf thickening and leaf area expansion, which ultimately promote overall plant growth. Large leaf areas and thickened leaves significantly contribute to the tree canopy structure, enabling it to capture more radiation, especially during periods of low radiation (Weraduwage et al., 2015). Leaf surface area in leaf photosynthesis and light capture is defined by its physiological and structural capacity (Longstreth and Nobel, 1981). Palisade cells behave as channels that transfer light deeper into the leaves and fairly spread it across them (Smith et al., 1997). According to Chartzoulakis et al. (1999), there is a correlation between the open surface area of palisade cells and photosynthesis. The large leaf area of the scion B74 may result from a higher photosynthetic rate and the channeling of assimilates into leaf area expansion (Weraduwage et al., 2015).

Grafting suitable scion rootstock combinations is critical for improving mango growth performance. In this research, B74 scion, when grafted onto KP rootstock, had the smallest canopy area (65.76 $\pm$ 4.39b) and volume (48.43 $\pm$ 4.92b) (Table 1), resulting in a reduced tree size (3.93 $\pm$ 0.13). This observation suggests that the B74 scion acts as a dwarfing scion. It can be an advantage to mango growers in the NT because of the dwarfing characteristics of B74; it can be grown in less planting distance (Zuazo et al., 2006; Mahajan et al., 2021; Dubey et al., 2021). We also analyzed B74 scion, which, when grafted onto KP rootstock, produced trees with a higher leaf SPAD value (45.46 $\pm$ 1.31a), a wider leaf area (6.52 $\pm$ 1.36), and a higher leaf dry weight (10.06 $\pm$ 1.11a) (Table 5), which means that there will be a higher amount of carbohydrate and photosynthetic activity. According to Malasi et al. (2017), higher photosynthetic rates result in increased leaf area. The nutrient resorption in leaves occurs in two ways: from senescing leaves to newer leaves and from senescing leaves to stems and/or roots (Brant and Chen, 2015), which suggests that if a leaf has a larger leaf area, there will be more nutrient resorption.

The growth of trees in nutrient-poor environments leads to reduced concentrations of nutrients in their leaves, slower rates of tissue turnover, and higher nutrient resorption efficiency. This data supports and aligns with prior research findings (Zhao et al., 2017). Since plants take most of their nutrients from the soil solution, the variation of soil nutrients heavily influences the nutrient dynamic in plants (Zhao et al., 2017). However, the nutrient concentration of a plant leaf varies due to various other reasons, such as the capacity of the soil to supply nutrients, the amount of nutrients that the plant can uptake through root activity, and the capacity of the plant to transfer nutrients from xylem to phloem (Yan et al., 2015). According to Yuan and Chen (2015), as nutrient availability increases, plant nutrient concentrations also increase, but the process of nutrient resorption decreases. Analyses revealed lower NC, PC, and MgC and higher NRE, PRE, and MgRE among the scions (Tables 3 and 5), indicating that species in nutrient-deprived environmental conditions have lower leaf nutrient concentrations and higher nutrient resorption efficiency (Aerts and Chapin, 1999). Lower NC and higher nutrient use efficiency are significant nutrient conservation mechanisms (Yan et al., 2015).

Based on these results, we may conclude that varieties with B74 grafted to KP are the most efficient in nutrient resorption, as measured by nutrient resorption proficiency and efficiency compared to NMBP 1201, NMBP 1243, and NMBP 4069. While scions NMBP 1201, NMBP 1243, and NMBP 4069 primarily focused on growing canopy volume and area, scion B74 focused its growth on expanding leaf area. The combination of rootstock and scion significantly affected canopy size, volume, SPAD value, leaf area, dry weight, and specific leaf weight ($P < 0.05$). Furthermore, B74 had exceptional nutrient resorption efficiency, along with its increased specific leaf weight, leaf dry weight, leaf area, and SPAD value, thus suggesting a potential enhancement in performance when grafted onto the KP.

Conclusion

According to the findings, the B74 scion grafted onto the KP is the most suitable combination of rootstock and scion for environmental adaptation. The tree develops a reduced canopy area and volume, making it well-suited for narrow planting distances. As a result, mango growers can plant more trees per hectare. Our research findings can assist mango growers in the NT region, where the soil nutrient content is deficient. Additionally, it can determine the optimal quantity of macronutrients required in the soil as per plant needs. The findings of our study can be valuable for mango producers in the NT region, as they can utilize the nutrient concentration and resorption efficiency data presented in this paper to select the most suitable mango variety for cultivation in nutrient-deficient soils.

Author Contributions
DY conceived and conceptualized the topic, collected data, designed the analysis, and wrote the paper. DY and AY performed the analysis and contributed to manuscript improvement. All authors contributed to the manuscript and approved the submitted version.

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Conflict of Interest
The authors indicate no conflict of interest in this work.

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