LenteraBio
p-ISSN: 2252-3979 e-ISSN: 2685-7871

Growth Responses of Mango (*Mangifera indica* L.) Seedlings from Grafting with Different Doses of NPK Fertilizer

Respon Pertumbuhan Bibit Mangga (Mangifera indica L.) Hasil Grafting dengan Pemberian Dosis Pupuk NPK yang Berbeda

Fahimatul Ilmiyah*, Rinie Pratiwi Puspitawati, Ahmad Bashri
Biology Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya
*e-mail: fahimatul33@gmail.com

Abstract. Mango is a horticultural crop whose distribution is mostly within the country. Mango exports are still not strong because the quality of mangoes is not in accordance with the wishes of foreign consumers. Therefore, it is necessary to provide superior seedlings through grafting and the addition of NPK fertilizer to support seedling growth. This study used wedge graft method on mango honey and arum manis 143. The purpose of the study was to determine the effect of NPK fertilization, determine the best NPK dosage and describe the anatomical structure of the grafting results. This research is experimental using Randomized Group Design (RGD) with 4 treatments and 6 replications. Quantitative data on plant height, number of leaves and scion diameter were tested using Anova Test and Duncan Test at 5% level. Anatomical qualitative data described the structure of the vessel bundle. The results showed that the application of NPK fertilizer affects plant height, number of leaves, scion diameter and vessel width on the grafted stem. The best treatment for plant height, number of leaves, and scion diameter is the 1.5 g NPK dose. Giving a dose of NPK 1.5 g produces the largest xylem and phloem width.
Keywords: anatomy; mango seedlings; grafting; growth; NPK fertilizer

Abstrak. *Mangga adalah tanaman hortikultura yang sebagian besar distribusinya berada di dalam negeri. Ekspor mangga masih kurang kuat karena kualitas mangga belum sesuai dengan keinginan konsumen luar negeri. Oleh karena itu, diperlukan penyediaan bibit unggul melalui grafting serta penambahan pupuk NPK untuk mendukung pertumbuhan bibit. Penelitian ini menggunakan metode wedge graft pada mangga madu dan arum manis 143. Tujuan penelitian untuk mengetahui pengaruh pemberian NPK, mengetahui dosis NPK terbaik serta mendeskripsikan struktur anatomi hasil grafting. Penelitian ini berupa eksperimental menggunakan Rancangan Acak Kelompok (RAK) dengan 4 perlakuan dan 6 kali ulangan. Data kuantitatif pada tinggi tanaman, jumlah daun dan diameter batang atas diuji menggunakan Uji Anova dan Uji Duncan taraf 5%. Data kualitatif anatomi dideskripsikan struktur berkas pembuluhnya. Hasil penelitian menunjukkan pemberian pupuk NPK berpengaruh terhadap tinggi tanaman, jumlah daun, diameter batang atas serta lebar berkas pembuluh pada batang hasil grafting. Perlakuan terbaik terhadap tinggi tanaman, jumlah daun, dan diameter batang atas yakni dosis NPK 1,5 g. Pemberian dosis NPK 1,5 g menghasilkan lebar xilem dan floem terbesar.*
Kata kunci: *anatomi; bibit mangga; grafting; pertumbuhan; pupuk NPK*

INTRODUCTION

Mango (*Mangifera indica* L.) is one of the horticultural crops in Indonesia that is a priority to be developed. Putu *et al* (2020) said that mango production in 2020 reached 2.9 million tons and increased 3.19% from 2019. One of the provinces with the largest mango production is East Java Province which contributes 44.6% to national production. The value of mango exports in 2020 increased by 32.29% from 2019, but most of the mangoes are distributed domestically while exports are not so strong because of the limited supply of quality and uniform mangoes, there is no guarantee of continuous supply, and the quality of mangoes has not met the wishes of foreign consumers, especially consumers of the United States, Japan and Europe who want quality assurance, and the safety of mango fruit free from pests and pesticide residues (Souza and Neto, 2012). In order for the export value to always increase, it is necessary to provide superior and quality seeds through vegetative plant propagation. The advantage of this technique is that the plants bear fruit quickly and produce offspring that are similar to their parents (Zhang *et al*., 2019).

There are various kinds of vegetative plant propagation techniques, one of which is grafting (Maulana *et al*., 2020). Grafting is a technique by uniting plant entries with other plant parts, namely the rootstock, so that a combination is formed that grows into a new plant. The rootstock holds the root system and the scion determines the quality of the fruit. This grafting technique has the benefits of producing new individuals that have several superior traits in terms of rooting and production, producing individuals whose fruit traits are the same as their parents, and regenerating without cutting down old trees, so there is no need for new seeds.

Research conducted by Limbongan and Djufry (2013) proved that the shoot grafting method has the highest success in cocoa seedlings compared to other methods such as cuttings, shoot grafting, side grafting, and somatic embryogenesis. Tedesco *et al* (2020) stated that problems with seedling connections after growth and development are still found, such as the growth rate will slow down and the connection will form like an elephant's foot. These problems indicate that the vessel network (xylem and phloem) between the scion and rootstock has been incompletely connected, therefore it is necessary to observe the connection results.

Limbongan and Yasin (2016) said that there are several grafting techniques such as approach grafting, whip and tongue grafting, wedge grafting, lateral grafting and others. This research uses wedge grafting with two varieties of plants that are still in one species and clan, namely honey mango as the rootstock and arum manis mango 143 as the scion. Honey mango was chosen as the rootstock because it has strong roots and good stem compatibility when grafted with other plants. Mango arum manis 143 was chosen as the scion because it has good fruit quality, sweet flavor, soft flesh texture, and thin seeds.

The success of mango seedling grafting can be seen from the fresh green scion, additional number of leaves and elongated scion shoots. The results of microscopic observations, if the connection field shows a faint and unified incision mark, then it indicates that the grafting of the two stems occurs well (Elsheery *et al*., 2020). The reduction of incision marks indicates that the cambium between the two stems has fused so that the transportation of nutrients and nutrients throughout the plant body occurs properly. Mango stems experience secondary thickening that develops from the cambium ring. The vascular cambium in mango will develop into mature cells such as vessel tissue, xylem, phloem, and phloem. The vascular cambium in mango will develop into mature cells such as vessel tissue, xylem, phloem, tracheids and others (Campbell *et al*., 2016).

One of the efforts to support the growth of mango seedlings is by adding adequate and balanced nutrients to the soil. One of the nutrients that can be given to mango seedlings is NPK fertilizer (16:16:16) with 16% Nitrogen (N), 16% Phosphorus (P_2O_5), and 16% Potassium (K_2O). The use of this fertilizer is more efficient, can reduce production costs, supplies the nutrients needed by plants with high concentrations, and is easily soluble so that plants can absorb nutrients effectively (Kaya, 2013). The dose of NPK fertilizer applied to seeds varies according to age. The older the plant, the more fertilizer the plant needs. The type and level of fertility of each soil is also different, so it is necessary to know the right dose of NPK fertilizer to reduce excessive fertilizer use. Through this research, it is hoped that the right dose of fertilizer can be obtained for the growth of mango seedlings.

MATERIALS AND METHODS

This research is an experimental research using RGD (Randomized Group Design) one factor. There were 4 treatments that were repeated 6 times so that errors in data collection could be minimized, resulting in 24 experimental units. This research was conducted from July 2023 - December 2024. Grafting of mango seedlings, application of NPK fertilizer, and observation of mango seedling growth were carried out in Sawah Village, Mulyorejo, Keraton District, Pasuruan, East Java. Microscopic observation of grafted stems in terms of anatomical characteristics of vessel bundles was conducted at the Microtechnical Laboratory, Building C10, Department of Biology, FMIPA Unesa. The tools used were a cutter knife, vial, tweezers, object glass, cover glass, dropper pipette, label paper, stainless base mold, light microscope, digital camera, brush, oven, microtome, and vacuum dessicator. The materials used were 70% FAA, distilled water, 70%, 80%, 96%, 100% alcohol, absolute xylol, paraffin, fastgreen, entellan, 0.5% safranin, and 30% glycerin.

Honey mango seedlings that were 2.5 months old were cut to a height of 35 cm, then split using a knife to a depth of 2 cm. The entry of arum manis mango 143 with 2-6 buds was cut to a length of 15 cm, then all leaves on the entry were removed. The base of the entry on both sides was slashed along 2 cm to form a wedge, then inserted into the crack of the rootstock and tied using plastic wrap. The entry is covered using transparent plastic and opened when the bud breaks. Watering is done once a day and weeding is done periodically. NPK fertilizer treatments were applied when the seedlings were 30 HSS, 60 HSS and 90 HSS with doses of 0 g, 0.5 g, 1 g and 1.5 g, respectively. Quantitative data obtained were then analyzed using Analysis of Variance. If the results of the analysis of variance are not significant, no further tests are carried out, but if they are significant, a Duncan's Multiple Range Test (DMRT) test at the 5% level is carried out using the Static Package for Social Sciences version 23 software. and observation.

The incisions used were transverse incisions with the paraffin preparation method. The stem samples were put into a bottle containing 70% FAA for 24 hours for the fixation process. Then the samples were washed with flowing water, then vacuumed with graded alcohol solutions (70%, 80%, 96%, 100%), alcohol:xylol solution (1:1) and xylol solution. Samples were placed in a mixture of xylol: paraffin (2:1), xylol: paraffin (1:1) and pure paraffin. Samples were molded in pure paraffin and cut using a microtome with a thickness of 15 µm. The sample pieces were placed on a glass slide that had been smeared with albumin, then immersed in xylol for 2x15 minutes. Samples were stained by immersion in xylol, 100%, 96%, 80%, 70% alcohol, safranin for 2 hours, distilled water, 70%, 80%, 96% alcohol, rinsed with distilled water, fastgreen for 30 seconds, 96%, 100% alcohol, and xylol. Samples were observed using a light microscope with magnifications of 4 x 10 and 10x10. The data results were then analyzed descriptively by observing the width of the xylem and phloem in the grafted stem.

RESULTS

The provision of different doses of NPK fertilizer on the grafted mango seedlings resulted in Duncan's test at the 5% level for the parameters of plant height and scion diameter at the age of 30 HSS, 45 HSS, 60 HSS, 75 HSS, and 90 HSS showing that the treatment of 0.5 g and 1 g NPK fertilizer doses was not significantly different from the treatment of 1.5 g NPK fertilizer doses. The treatment of 0 g NPK fertilizer dose is also not significantly different from 0.5 g and 1 g NPK fertilizer doses, the absence of a real difference occurs because the treatment of 0.5 g and 1 g NPK fertilizer doses has the same notation.

Duncan's test results at the 5% level for the number of leaves of mango seedlings at the age of 30 HSS, 45 HSS, 60 HSS, 75 HSS, and 90 HSS show that the dose of NPK fertilizer 1.5 g is significantly different from the treatment of NPK fertilizer doses of 0 g, 0.5 g and 1 g, no significant difference occurs in the treatment of NPK fertilizer doses of 0 g, 0.5 g and 1 g because they have the same notation. Duncan test results of plant height parameters, scion diameter and number of leaves are presented in table 1.

Table 1. Duncan's test results for plant height, scion diameter, and number of leaves

Parameters	Age	NPK fertilizer dosage (g)*			
		0 g	**0,5 g**	**1 g**	**1,5 g**
Plant height	30 HSS	62.66^{ab}	54.33^{a}	54.33^{a}	87.66^{b}
	45 HSS	62.70^{ab}	54.43^{a}	54.50^{a}	87.83^{b}
	60 HSS	62.71^{ab}	54.46^{a}	54.65^{a}	88.10^{b}
	75 HSS	62.73^{ab}	54.50^{a}	54.75^{a}	88.28^{b}
	90 HSS	62.77^{ab}	54.55^{a}	54.78^{a}	88.38^{b}
Scion diameter	30 HSS	6.23^{ab}	5.40^{a}	5.38^{a}	8.70^{b}
	45 HSS	6.25^{ab}	5.40^{a}	5.40^{a}	8.71^{b}
	60 HSS	6.25^{ab}	5.41^{a}	5.41^{a}	8.73^{b}
	75 HSS	6.25^{ab}	5.43^{a}	5.41^{a}	8.75^{b}
	90 HSS	6.26^{ab}	5.43^{a}	5.43^{a}	8.76^{b}
Number of leaves	30 HSS	6.16^{a}	6.33^{a}	5.50^{a}	10.00^{b}
	45 HSS	6.66^{a}	6.83^{a}	6.00^{a}	10.50^{b}
	60 HSS	7.16^{a}	7.33^{a}	6.16^{a}	11.00^{b}
	75 HSS	7.50^{a}	7.50^{a}	7.00^{a}	11.50^{b}
	90 HSS	8.00^{a}	8.16^{a}	7.50^{a}	12.33^{b}

Description: *)Duncan test results at 5% level if the numbers followed by the same letter in each column show the results are not significantly different between treatments.

Observations of xylem and phloem width were made on the stem area of the grafted seedlings from the control treatment compared to the NPK fertilizer treatments of 0.5 g, 1 g, and 1.5 g doses. The results of xylem and phloem width observations are presented in Fig. 1, 2, and 3.

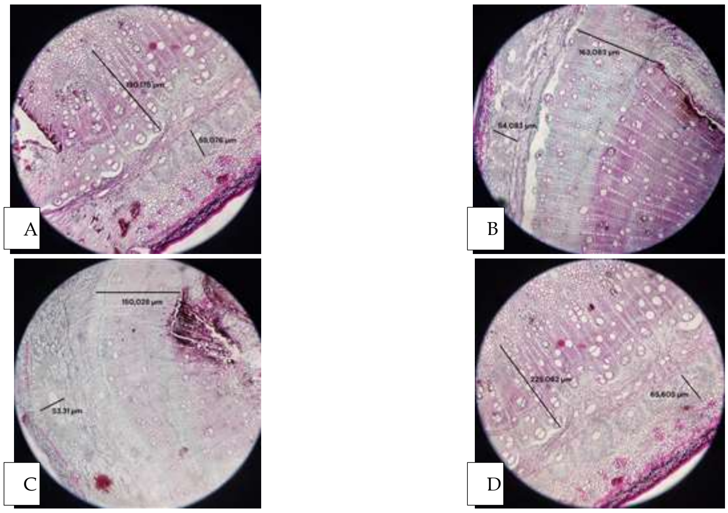

Fig 1 Measurement of xylem and phloem width at station 3 Source: Personal documentation, 2024. Description: A) control, B) 0.5 g NPK dose, C) 1 g NPK dose, D) 1.5 g NPK dose.

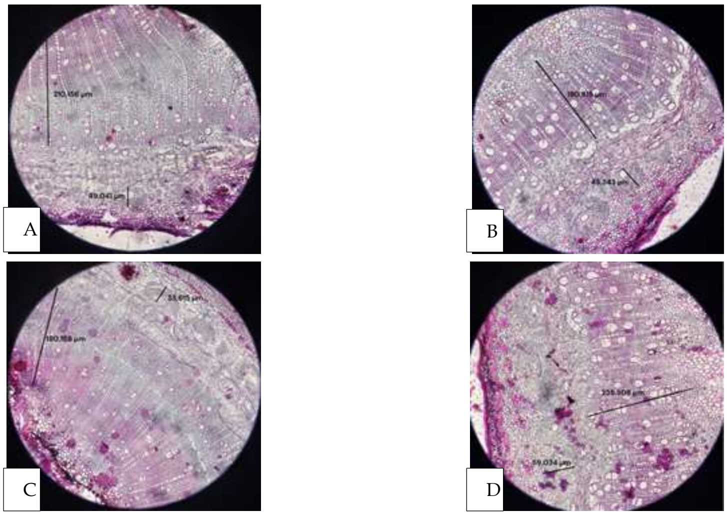

Fig 2 Measurement of xylem and phloem width at station 3 Source: Personal documentation, 2024. Description: A) control, B) 0.5 g NPK dose, C) 1 g NPK dose, D) 1.5 g NPK dose.

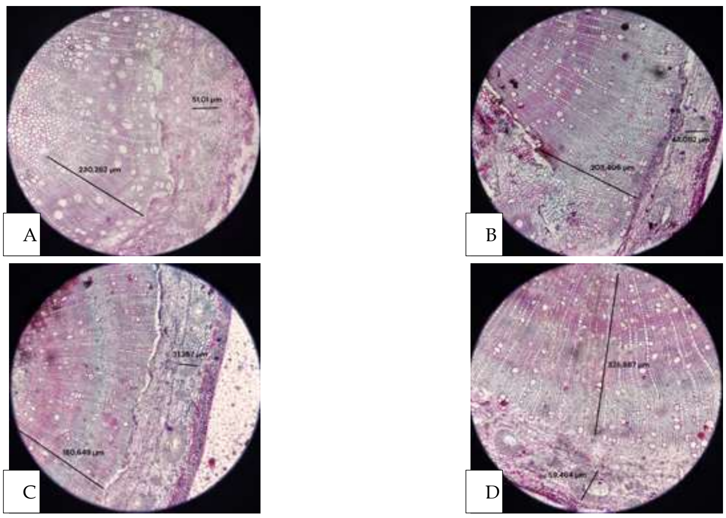

Fig 3 Measurement of xylem and phloem width at station 3 Source: Personal documentation, 2024. Description: A) control, B) 0.5 g NPK dose, C) 1 g NPK dose, D) 1.5 g NPK dose**.**

DISCUSSION

Observations of mango seedling growth were made when the seedlings were 30 HSS, 45 HSS, 60 HSS, 75 HSS, and 90 HSS. Plant height growth was measured using a ruler starting from the tip of the leaf or the highest plant tip to the base of the stem. The height of mango seedlings increases every week, in the vegetative phase the increasing age of the plant, the height of the resulting plant increases. Mango seedling height is an important part of knowing the plant's response to the treatment that has been given. Growth is strongly influenced by the suitability of the environment and the availability of nutrients in the soil. Growth will be optimal if the environment and all nutrients are in accordance with the needs of plants. Conversely, if the environment is not suitable and the nutrients are not balanced, then growth will be inhibited. The dose of NPK fertilizer affects the growth of mango seedlings from grafting. This happens because the application of NPK fertilizer can make the content of nutrients in the soil increase so that it affects the growth of plant height. The different doses of NPK fertilizer given cause differences in the level of fertility produced physically, chemically and biologically so that it has a different effect on the growth of mango seeds, where each plant will make optimal use of environmental conditions in accordance with the level of soil fertility (Kriswantoro *et al*., 2016).

The growth stage of plant height actually requires N and P elements, these elements are found in NPK fertilizers. NPK elements are provided to stimulate physiological processes such as plant height increase, where cells divide and require nutrients in sufficient quantities for plants to absorb through the roots. Nutrients absorbed by plants are found in the soil solution in ionic form. Roots grow through soil pores and contact ions in the soil solution. Ion absorption occurs through cation exchange (Agustina, 2016). Nitrogen (N) will be absorbed in the form of nitrate (NO^{3-}) or ammonium (NH^{4+}) ions, Phosphorus (P) will be absorbed in the form of phosphate ions (PO_4^{3-}), Potassium (K) will be absorbed in the form of potassium ions (K^+). After being absorbed through the roots, NPK will be transported through plant vessels to other plant parts. Nitrogen will be transported to leaves and other vegetative parts for growth and metabolism. Phosphorus will be transported to the roots and leaves to facilitate root growth and development and photosynthesis. Potassium will be transported to various parts of the plant to regulate cell osmotic pressure, enzyme activation, and other functions. NPK absorbed by plants will be used for various metabolic and growth processes including protein synthesis, cell structure formation, and energy production. Newly formed plant parts from grafting will use NPK for optimal growth and development. Some NPK may also be stored in the plant tissue for later use.

NPK fertilizers have various main functions, according to Handayani *et al*., (2015) Phosphorus functions in the photosynthesis process. The absorption of phosphorus and potassium by plants can be used as the main ingredient in cell division so that plant height increases. The environment also affects plant height such as sunlight. Light is an important factor in the photosynthesis process, if the light obtained by mango seeds is lacking, it causes etiolation with the characteristics of a fast-growing but weak stem, small leaf size, thin and pale leaf color. Although the need for nutrients is sufficient but does not get optimal light, then plant growth is disrupted.

The number of leaves that grow on mango seedlings is calculated when the seedlings are 30 HSS with the condition that the leaves have opened completely and are green in color. The calculation of the number of leaves was done when the mango seedlings were 30 HSS, 45 HSS, 60 HSS, 75 HSS, and 90 HSS. Leaves play a role in plant survival because they act as a place of respiration, photosynthesis, and transpiration in plants. Leaves produce photosynthates that are used to form new tissues in the connection area so that the growth or connection between the entres and rootstock will be optimized. Macro and micro nutrients affect leaf growth. Nitrogen (N) is one of the nutrients that has a role to stimulate plant vegetative growth, especially the growth of leaves, stems, roots, and branches. These nutrients must be available to plants before new cells are formed to produce leaves, plant height and other growth (Parsaulian *et al*., 2012). Plants absorb nitrogen when actively growing and not always at the same level of need. The maximum amount of nitrogen absorbed per unit weight of the plant per day when the plant is young, and as the plant ages, the amount of nitrogen absorbed gradually decreases. Based on the data obtained, it can be seen that the highest number of leaves is obtained at the dose of 1.5 g NPK fertilizer so that the more the dose of NPK fertilizer given, the increase in the number of leaves increases (Kriswantoro *et al*., 2016).

The formation of new leaves is the development of the apical meristem of the shoot. Parsaulian *et al* (2012) stated that leaves grow due to the process of division, elongation, and cell differentiation in meristem tissues in lateral buds and terminal buds. The faster the three processes, the faster the leaves will be formed. The increase in the number of leaves is in line with the growth of shoot length, if the shoot growth is getting longer. Plants carry out metabolic processes necessary for their growth and development. Sugar transport occurs in phloem tissue which is important for growth, metabolism and storage in plants. The formation of sugar, especially sucrose, is produced in leaves through photosynthesis. Leaf cells use light energy to convert CO_2 and H_2O into glucose and fructose through chemical reactions catalyzed by enzymes in chloroplasts (Tumanggor *et al.*, 2023). Sugar is transferred from the leaves to plant parts such as roots, flowers or fruits through the process of phloem translocation. Sugar transport in the phloem involves an active transport process. The phloem consists of a series of cells called cylindrical elements of vessels that form small-diameter tubes throughout the plant (Jyske and Holtta, 2015). The flow of sugars in the phloem is often accompanied by the flow of water to form a phloem fluid called plant juice that enables the transportation of significant amounts of sugars through the plant's vascular network. Sugar transport in plants is a complex and important process that ensures the efficient distribution of energy and the provision of essential materials for the growth and metabolism of the whole plant.

The diameter of the scion was measured using a caliper by placing it in the connection area. Measurement of scion diameter was done when the mango seedlings were 30 HSS, 45 HSS, 60 HSS, 75 HSS, and 90 HSS. The stem diameter increased every week, because the older the plant, the stem diameter increases. The dose of NPK fertilizer affects the stem diameter of grafted mango seedlings. This happens because the plant has absorbed NPK fertilizer optimally so that it can increase the size of the stem diameter. This is supported by the statement of Marliah *et al* (2012) that plants will grow better if all the necessary nutrients are available and in sufficient quantities. Nutrient P from NPK fertilizer has a role in the formation of tissues in plants, one of which is the stem organ so that the diameter of the stem will increase. Sasmita *et al* (2020) stated that the stem develops with the help of the element P because it functions to help cell division.

Plant stems are plant organs where plant growth accumulates, especially when they are young, so that the presence of nutrients can encourage plant vegetative growth, for example, such as the formation of chlorophyll in leaves so as to increase the rate of photosynthesis process (Armando *et al.*, 2020). The faster the photosynthesis process, the more photosynthate is produced so that it will produce a large stem circumference. The entry used for grafting must contain adequate food reserves to produce wound cover tissue, so that a network of vessels is formed that transports nutrient flow from the rootstock so that it can support plant survival. Stems have active cell division zones and enlargement zones, if the carbohydrate content is balanced and sufficient, the process of cell division and enlargement will continue to increase.

The grafted seedlings need to be watered and fertilized. Fertilization can be done by using NPK fertilizer applied to the soil at a dose of 1-2 grams/plant within a period of once a month (Susiyanti *et al.*, 2019). n this study, the application of NPK at a dose of 1.5 g gave the best effect on the parameters of seedling height, number of leaves, and scion diameter because this dose was able to meet the needs of plant nutrients so that the growth of mango seedlings at this dose was faster than the treatments of 0 g; 0.5 g; and 1 g. This is in line with the research of Dewi *et al* (2022) that the provision of NPK fertilizer has a very significant effect on the parameters of plant height, number of leaves, and stem diameter, thus showing that the macro nutrients contained in NPK fertilizer function to support the growth of mango seeds because the content of nutrients needed by plants is balanced. Suwarno (2013) said that plants will grow well if the necessary nutrients are provided in balanced amounts, especially the macro nutrients N, P and K.

The role of each of these elements in increasing the growth of plant height, number of leaves, and stem diameter. Nitrogen is an essential element in the formation of proteins, chlorophyll, nucleic acids, and various other compounds required for plant growth (Firmansyah *et al.*, 2017). Adequate nitrogen availability enhances the process of photosynthesis, which produces energy and organic matter necessary for the growth and development of plant cells. Nitrogen also affects the formation and development of leaves, which are the main place where photosynthesis occurs. Adequate nitrogen availability can increase the number and size of leaves, as well as increase the leaf surface area for sunlight absorption.

Phosphorus is important in the formation of DNA, RNA, ATP, and phospholipids required for the synthesis and regulation of various metabolic processes in plants. Phosphorus also plays an important role in root growth and development. Healthy and strong roots support the absorption of sufficient water and nutrients to support the vegetative growth of the plant (Napitupulu, 2023). In stem growth, phosphorus helps in the formation of tissues that support strong stem growth and larger diameter. Potassium is a cation ion that is important in the regulation of osmotic pressure, stomatal opening, and enzyme activity. Adequate potassium availability can increase plant tolerance to environmental stresses such as drought and temperature extremes. Potassium also plays an important role in the regulation of growth and differentiation of plant cells and can contribute to the formation of larger cells resulting in increased stem diameter. Adequate nutrition of these three elements gives plants greater potential to increase growth in height, number of leaves, and stem diameter.

The rootstock and scion should have similar diameters when grafting for greater success of union with the vascular cambium (Soto *et al*., 2016). The presence of tissue with meristematic ability is essential to initiate the healing and union process such as parenchyma tissue that can differentiate and divide when there is damage (Chano *et al*., 2015). Mango is a dicotyledonous plant whose stem undergoes secondary thickening of the cambium ring (Gathe and Watson, 2016). Based on observations that have been made using a binocular microscope with a magnification of 10x10, several tissues in the anatomy of the grafted mango stem can be seen with transverse incisions in Fig 1, 2 and 3. The first layer from the outside is the periderm (epidermis substitute) as a protector in secondary growth. The next layer, the cortex, consists of round, thin-walled cells, located in a circle, there are cavities between the cells that are responsible for storing and exchanging air. The cortex has a thickness that varies depending on the size, age, and level of secondary growth or plant body parts (Jayanti, 2017). The core of the stem is the network of vessels forming a cylinder between the cortex and pith.

Stems in mango seedlings have open collateral-type transport bundles with xylem located on the inside and phloem on the outside and between the two there is cambium. Xylem is a complex network consisting of living cells and dead cells that function to carry several hundred water to the leaves, and most of it is evaporated into the air or respiration (Jensen *et al*., 2016). Phloem tissue functions as a carrier of organic matter. Xylem and phloem are formed through differentiation and procambium. Based on the anatomical observation of the stem of the grafted mango seed, a transport beam has been formed between the entres and the rootstock. The formation of a vascular network between the rootstock and the entres will repair the vessel system in plants that are disturbed due to wounds during grafting (Asahina and Satoh, 2015) so that the process of transporting water and nutrients in plants can occur properly. The success of grafting mango seedlings when microscopically observed, when the connection field shows a faint and unified incision scar, it indicates that the connection of the two stems occurs well (Elsheery *et al*., 2020). The reduction of incision scars in the connection area means that the vascular cambium between the entres and the rootstock has fused so that the transportation of nutrients and nutrients throughout the plant body occurs properly.

The transport bundles in the stem of grafted mango seedlings have different xylem and phloem widths. The xylem width of the grafted mango seedling stem without treatment (control) ranged from 190.175 µm-230.262 µm and phloem width ranged from 49.041 µm-59.076 µm. The treatment of 0.5 g NPK fertilizer dose has xylem width with a range of 163.083 µm-208.406 µm and phloem width ranging from 45.343 µm-54.083 µm. Then the treatment of 1 g NPK fertilizer dose has a xylem width with a range of 150.028 µm-180.649 µm and phloem width ranging from 31.257 µm-53.310 µm. The treatment of 1.5 g NPK fertilizer dose has xylem width with a range of 225.062 µm-325.687 µm and phloem width ranging from 59.034 µm-65.605 µm. The xylem parenchyma cells look bigger than the phloem cells Jacoeb and Purwaningsih (2011). The difference in width of xylem and phloem is because each plant has a different ability to absorb nutrients. The width of the xylem determines the potential for nutrient transportation, if the width of the xylem is small, the strength of water and mineral transportation through the stem will be reduced (Rashedy *et al*., 2014).

The xylem being larger or wider than the phloem is usually due to differences in their function and structure (Jyske and Holtta, 2015). Xylem is the tissue that transports water and minerals from the roots to the upper parts of the plant, such as stems and leaves. The phloem is responsible for the transport of synthesized nutrients, such as sugar from the leaves to other parts of the plant. Xylem must handle the considerable flow of water from the roots to the leaves for the photosynthesis process and structural support. Therefore, xylem requires more space to accommodate the large water flow. On the other hand, phloem has a slower flow as it transports smaller organic nutrients in fewer quantities.

The xylem generally consists of tracheid elements and vessel elements that serve to transport water efficiently. The phloem consists of parenchyma cells and smaller cylindrical vessel elements because the organic nutrients it transports do not require as much space as the xylem (Jyske and Holtta, 2015). The xylem also generates high hydrostatic pressure to transport water under certain conditions, such as in actively transpiring plants. The larger structure allows the xylem to withstand hydrostatic pressure better than the phloem, so the wider size of the xylem is an adaptation to fulfill the function in the plant's transportation system efficiently. The most central part contains pith. The characteristics of pith are smaller in size and thicker cell walls. The deeper, the size of the pith parenchyma cells gets bigger and the cell walls get thinner (Jayanti, 2017).

Giving a dose of 1.5 g NPK fertilizer produces a greater width of xylem and phloem than the dose of 0 g, 0.5 g, and 1 g. The greater the application of NPK fertilizer, the greater the width of xylem and phloem. Plant growth is driven by cell division and elongation, which require large amounts of nutrients. The addition of phosphorus nutrients significantly increases the thickness of xylem in the stem (Xu *et al*., 2020). This is supported by research conducted by Cuzzuol *et al* (2013) that the availability of NPK nutrients can support an increase in the diameter or width of *Caesalpinia echinata* Lam vessel bundles. Based on research conducted by Dewi *et al* (2022), giving a dose of 1 g NPK fertilizer is more optimal in the parameters of plant height, number of leaves, and stem diameter. Giving NPK fertilizer in large quantities can endanger growth and make plants die. Giving too little NPK fertilizer also reduces the need for nutrients for plants so that plant growth will be inhibited.

Nutrients N, P, and K are needed during the initial process of growth to production. Plants need nitrogen for protein synthesis and other important components in cell formation as well as for the production of chlorophyll which makes the leaves green. Sufficient availability of chlorophyll in the leaves can increase the ability to absorb sunlight, increase the process of photosynthesis, and produce organic matter as a source of energy for cell growth and metabolic activities. Manasikana *et al* (2019) stated that nitrogen can affect plant height growth and stimulate overall growth, so that these nutrients are needed during vegetative growth of plants including the formation of new tissues after the grafting process. Nitrogen is important in the formation of proteins, amino acids, and various other compounds in plant cells. Proteins are the main structural component in plant cells including in the formation of xylem and phloem cell walls. Nitrogen deficiency can inhibit stem and leaf growth, and can slow down tissue healing and fusion between the scion and rootstock. Adequate nitrogen availability can increase cambium activity and cell division, and accelerate the formation of new vascular tissue in the grafting area.

Phosphorus is an important component of nucleic acids, phospholipids, ATP and helps in the formation of plant cell structures, including the formation of vascular networks. Phosphorus deficiency can inhibit root growth and new tissue formation, thus slowing down the healing process after grafting (Agromedia, 2011). Phosphorus is also important during the synthesis of nucleic acids and phospholipids for the formation and maintenance of cell structures, including the growth and development of xylem and phloem tissues. ATP, as an energy source, supports various metabolic processes required for the synthesis of cell components, including the formation of vascular tissues such as xylem and phloem.

Potassium is a cation ion that is essential for the regulation of osmotic pressure in cells and stomatal function. Regulation of osmotic pressure affects the rate of transpiration which in turn can affect the flow of water and nutrients from roots to leaves via the xylem. Proper stomatal function is important for gas exchange and water uptake by the roots which ultimately affects the availability of water and nutrients for vascular tissue growth and development. Although N, P, and K do not directly cause the physical expansion of xylem and phloem, they are essential in providing the resources and energy required for the synthesis of cell components and metabolic processes that support the growth and development of xylem and phloem tissues. The element potassium plays a role in stimulating the transport of carbohydrates from leaves to plant organs (Agustina, 2016). The availability of potassium is sufficient to encourage root growth and the formation of vascular tissues that are important for the union between the scion and rootstock after the grafting process. Potassium also plays a role in activating enzymes involved in plant metabolism and is required for wound healing and new tissue growth.

CONCLUSION

Doses of NPK fertilizer (0 g; 0.5 g; 1 g; and 1.5 g) affect plant height, number of leaves, scion diameter, and width of vessel bundles (xylem and phloem) on the stem of grafted mango seedlings. The best treatment for plant height, number of leaves, and scion diameter of grafted mango seedlings was 1.5 g NPK fertilizer dose. Dosing 1.5 g of NPK fertilizer produces greater width of xylem and phloem compared to doses of 0 g, 0.5 g, and 1 g of NPK fertilizer.

REFERENCES

Agustina L, 2016. *Dasar Nutrisi Tanaman*. Jakarta: PT Rineka Cipta.

Agromedia R, 2011. *Bertanam mangga di dalam pot dan di kebun*. Jakarta Selatan: PT AgroMedia Pustaka.

Armando YG, Maryani AT and Syarif, 2020. The effectiveness of providing vulanic ash (tuff vulcan) and dolomite as amelioran materials on the growth of immature liberica coffee plants in peat land of Mekar Jaya Village. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *Vol. 4(2): 204-211*

Asahina M and Satoh S, 2015. Molecular and physiological mechanisms regulating tissue reunion in incised plant tissues. *Journal of plant research*, *Vol. 128: 381-388*.

Campbell NA, Urry LA, Cain ML, Wasserman SA, Minorsky PV and Reece JB, 2016. *Campbell Biology 11th Edition*. USA: Pearson Higher Education

Chano V, López R, Pita P, Collada C and Soto A, 2015. Proliferation of axial parenchymatic xylem cells is a key step in wound closure of girdled stems in *Pinus canariensis*. *BMC Plant Biol*, *Vol. 15: 1–13*

Cuzzuol GRF, Milanez CRD, Gomes JML, Labate CA and Canal EC, 2013. Relationship between N, P, and K and the quality and stem structural characteristics of *Caesalpinia echinata* Lam. *Plants. Trees, Vol. 27(5): 1477-84.*

Dewi S, Hayati E and Kesumawati E, 2022. Pertumbuhan Bibit Alpukat (*Persea amerina* Mill) Hasil Sambung Pucuk Akibat Media Tanam dan Dosis Pupuk NPK. *Jurnal Floratek, Vol. 17(1): 36-46*.

Elsheery NI, Helaly MN, Omar SA, John SV, Zabochnicka-Świątek M, Kalaji HM and Rastogi A, 2020. Physiological and molecular mechanisms of salinity tolerance in grafted cucumber. *South African Journal of Botany*. *Vol. 130: 90-102*.

Firmansyah I, Syakir M and Lukman L, 2017. Pengaruh kombinasi dosis pupuk N, P, dan K terhadap pertumbuhan dan hasil tanaman terung (*Solanum melongena* L.). *Indonesian Agency for Agricultural Research and Development. Vol. 27(1): 69-78*

Gathe J and Watson L, 2016. *Mangifera* L. Australia: FloraBase-Western Australian Flora.

Handayani Y, Sjofjan J and Yetti H, 2015. Campuran kompos tandan kosong kelapa sawit dengan kompos lcc dan pupuk fosfor terhadap pertumbuhan dan hasil sorgum (*Sorghum bicolor* (L.)). *Jom Faperta, Vol. 2(1): 1-14.*

Jacoeb AM and Purwaningsih S, 2011. Anatomi, komponen bioaktif dan aktivitas antioksidan daun mangrove api-api (*Avicennia marina*). *Jurnal Pengolahan Hasil Perikanan Indonesia*, *Vol. 14(2): 143-152*

Jayanti ET, 2017. Profil anatomi batang kacang komak (*Lablab purpureus* (L.) Sweet) lokal Pulau Lombok. *Biota*, *Vol. 10(2): 151-164.*

Jensen KH, Berg Sorensen K, Bruus H, Holbrook NM, Liesche J, Schulz A and Bohr T, 2016. Sap flow and sugar transport in plants. *Reviews of Modern Physics*, *Vol. 88(3): 035007*

Jyske T and Holtta T, 2015. Comparison of phloem and xylem hydraulic architecture in P icea abies stems. *New phytoloist, Vol. 205(01):102-115*

Kaya E, 2013. Pengaruh kompos jerami dan pupuk NPK terhadap N-tersedia tanah, serapan-N, pertumbuhan, dan hasil padi sawah (*Oryza sativa* L). *Agrologia*, *Vol. 2(1): 288785*.

Kriswantoro HK, Safriyani E and Bahri S, 2016. Pemberian pupuk organik dan pupuk NPK pada tanaman jagung manis (*Zea mays* saccharata Sturt). *Klorofil: Jurnal Penelitian Ilmu-Ilmu Pertanian*, *Vol. 11(1): 1-6*.

Limbongan J and Yasin M, 2016. *Teknologi Multiplikasi Vegetatif Tanaman Budidaya*. Jakarta: IAARD Press.

Limbongan J and Djufry F, 2013. Pengembangan Teknologi Sambung Pucuk sebagai Alternatif Pilihan Perbanyakan Bibit Kakao. *J Penelitian dan Pengembangan P, Vol. 32(4): 166– 172*.

Manasikana A, Lianah and Kusrinah, 2019. Pengaruh Dosis Rhizobium Serta Macam Pupuk NPK Terhadap Pertumbuhan Tanaman Kedelai (*Glycine max*) Varietas Anjasmoro. *Journal of Biology and Applied Biology*, *Vol. 2(1): 133-143*

Marliah A, Hayati M and Muliansyah I, 2012. *Pemanfaatan Pupuk Organik Cair terhadap Pertumbuhan dan Hasil Beberapa Varietas Tomat* (*Lycopersicum esculentum* Mill.). Aceh: Fakultas Pertanian Universitas Syiah Kuala Banda Aceh.

Maulana O, Rosmaiti R and Syahri M, 2020. Keberhasilan pertautan sambung pucuk beberapa varietas mangga (*Mangifera indica*) dengan panjang entres yang berbeda. *Agrotekma: Jurnal Agroteknologi dan Ilmu Pertanian, Vol. 5(1): 12-22.*

Napitupulu R, 2023. Effect of coffee husk compost on the groth and yield of red chili plants in defferent planting media composition. *Agritech: Jurnal Fakultas Pertanian Universitas Muhammadiyah Purokerto. Vol 25(1): 121-131*

Parsaulian T, Bandem PD and Patriani D, 2012. Pengaruh panjang entris terhadap keberhasilan sambung pucuk bibit jambu air. *Jurnal Sains Mahasiswa Pertanian, Vol. 1(1): 1–9*

Putu NS, Agung S, Zelani N, Amelia DI, Ike MP, Wati S and Satria KA, 2020. *Statistik Hortikultura 2020*. Jakarta: Badan Pusat Statistik RI

Rashedy AA, Kheshin MAE and Allatif AMA, 2014. Histological parameters related to dwarfism in some mango cultivars. *World Journal of Agricultural Sciences*, *Vol. 10(5): 216-222*.

Sasmita MWS, Nurhatika S, and Muhibuddin A, 2020. Pengaruh dosis mikoriza arbuskular pada media AMB-P0K terhadap pertumbuhan tanaman tembakau (*Nicotiana tabacum* var. *Somporis*). *Jurnal Sains dan Seni ITS, Vol. 8(2): 43–48*.

Soto-Landero F, Alcaraz-Meléndez L, Angulo-Escalante MA, Reynoso-Granados T, Orduño-Cruz A, Cruz-Hernández P and Herrera Cedano F, 2016. Anatomical compatibility of *Jatropha curcas* (L.) graft on *Jatropha cinerea* (Ortega) Muell. *Arg Rootstock Nova Scientia, Vol. 8: 249–262*

Souza RC and Neto JA, 2012. An investigation about Brazilian mango and grape exports. *British Food J, Vol. 114(10): 1432-44*

Susiyanti S, Nurmayulis N, Mulyati S, Sjaifuddin S and Eris FR, 2019. Pemberdayaan Masyarakat Melalui Peningkatan Kualitas Bibit Tanaman Buah dengan Metode Mini Grafting. *Jurnal Pengabdian Dinamika, Vol. 6(1): 59-69*

Suwarno VS, 2013. Respon pertumbuhan dan produksi tanaman mentimun (*Cucumis sativus* L.) melalui perlakuan pupuk NPK pelangi. *Jurnal Karya Ilmiah Mahasiswa Universitas Negeri Gorontalo, Vol. 1(1): 1-12.*

Tedesco S, Pina A, Fevereiro P and Kragler F, 2020. A phenotypic search on graft compatibility in grapevine. *Agronomy, Vol. 10(5): 706.*

Tumanggor L, Fitria R, Weni M, and Tukan MMNM, 2023. *Metabolisme zat gizi*. Surabaya: Cipta Media Nusantara.

Xu F, Chu C and Xu Z, 2020. Effects of different fertilizer formulas on the growth of loquat rootstocks and stem lignification. *Scientific Reports, Vol. 10(1): 1033*

Zhang X, Zhang F, Wang J, Lin L, Liao MA, Tang Y, Sun G, Wang X, Lv, X, Deng Q and Chen C, 2019. Cutting after grafting affects the growth and cadmium accumulation of *Nasturtium officinale*. *Environmental Science and Pollution Research, Vol. 26: 15436-15442*.

Article History:
Received: 3 June 2024
Revised: 17 July 2024
Available online: 20 August 2024
Published: 30 September 2024

Authors:
Fahimatul Ilmiyah, Biology Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur (60231), e-mail: fahimatul33@gmail.com
Rinie Pratiwi Puspitawati, Biology Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur (60231), e-mail: riniepratiwi@unesa.ac.id
Ahmad Bashri, Biology Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur (60231), e-mail: ahmadbashri@unesa.ac.id

How to cite this article:
Ilmiyah F, Puspitawati RP, Bashri A, 2024. Growth Responses of Mango (*Mangifera indica* L.) Seedlings from Grafting with Different Doses of NPK Fertilizer. LenteraBio; 13(3): 411-420.