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Effect of Various Fertilizer Rates of Water-Soluble NPK on Growth, Photosynthetic Pigments, Yield and Fruit Quality of Watermelon

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Abstract**—** Commercial watermelon farming in open fields relies on granular fertilizer to increase yield and quality. Nevertheless, granular fertilizer application is inefficient, leads to poor nutrient absorption, and can be hazardous. To address this challenges, the application of water soluble fertilizer through fertigation system is the best solution. Hence, an experiment was conducted to evaluate and select the optimum water soluble NPK rates used on growth, photosynthetic pigments, yield and fruit quality of watermelon. Watermelon seedlings were subjected to four water-soluble NPK fertilizer rates at 75%, 100% (Control – 108 kg N, 247.32 kg P and 153.6 kg K), 125% and 150% based on common practices of NPK granular fertilizer used in watermelon at open field planting system for 65 days. Fertilizer rates induced at 125% significantly increased stem diameter and leaf area index of watermelon as compared to control at 15% and 13.1% respectively. Whereas, application of fertilizer at 150% significantly increased the chlorophyll a and b with the respective increments of 3.71% and 10.22%. In addition, both fertilizer rates of 125% and 150% were significantly increased the fruiting day, fruit weight and total soluble solid (TSS) when compared to control. To sum up, increasing 25% NPK standard fertilizer rate (125%) could be promising for watermelon cultivation. Further trials in commercial scale need to be undertaken to verify the selected rate identified in this study

Keywords**—** Watermelon, Fertigation, Water-soluble fertilizer, NPK.

I. INTRODUCTION

Watermelon is an herbaceous creeper that belonging to the Cucurbitaceae plant family and it is classified as a short-term horticultural crop. With over 750 species and approximately 100 genera (Enujeke, 2013), it is widely consumed globally due to its rich nutrient profile, including phytonutrients and antioxidants such as lycopene (Reetu and Tomar, 2017). Successful cultivation of watermelon relies heavily on factors like fertilization. In Malaysia, the current fertilization strategy for watermelon primarily depends on granular fertilizers. However, this method is labor-intensive, time-consuming, and often leads to insufficient nutrient uptake due to unpredictable rainfall, while also posing risks of soil toxicity. Inadequate nutrient absorption, caused by soil nutrient deficiencies, results in poor crop growth and quality (Aluko et al., 2014). Beyond economic concerns, excessive fertilization, particularly of nitrogen, has been associated with groundwater nitrate pollution (Craswell, 2021) and increased pest and disease outbreaks (Gomez-Trejo et al., 2021). To mitigate these challenges, the use of water-soluble fertilizers in a fertigation system presents a promising solution, ensuring efficient nutrient absorption by plants while minimizing waste.

Fertigation, widely adopted in commercial agriculture and horticulture, is particularly effective in protected farming systems. It enhances resource efficiency, boosts crop yield and quality, reduces environmental pollution, and supports sustainable agricultural practices (Lin et al., 2020). This method ensures precise and uniform nutrient delivery to the root zone, where active roots are concentrated. Compared to traditional fertilization, drip fertigation improves water and fertilizer use efficiency while enhancing crop yield and quality (Ma et al., 2022). Studies have demonstrated its benefits: apple yields increased by 29.2%, titratable acidity by 4.9%, and total soluble solids (TSS) by 5.3% (Kumar et al., 2016). Similarly, date palm yields rose by 41%, with a 66% reduction in fertilizer use (Al-Qurashi et al., 2016). Fertigation also increased leaf nitrogen and stem diameter in peach plants while reducing nitrogen fertilizer application by 25% to 50% (Casamali et al., 2021). In Florida's citrus farms, drip fertigation boosted fruit output by 9%, total sugar content by 8%, and saved

7% of fertilizer (Ma et al., 2022). With advancements in technology, the Internet of Things (IoT) has found extensive applications in agriculture, including fertigation systems. IoT enables precision agriculture, enhancing long-term profitability, productivity, and product quality (Ruan et al., 2020). Integrating IoT into fertigation systems allows for precise fertilization, optimal nutrient uptake, and significant time and energy savings in watermelon cultivation.

To implement a smart fertigation system with IoT monitoring, the development of water-soluble NPK fertilizers is essential. These fertilizers, used in sprinkler or drip irrigation systems, enhance the production and quality of fruits and vegetables. They typically consist of balanced combinations of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and micronutrients (Malhotra, 2016). Optimal fertilization is a critical agricultural practice for achieving higher watermelon yields. Nitrogen (N), phosphorus (P), and potassium (K) are vital for plant growth, development, and productivity, with watermelon having particularly high demands for these nutrients (Loka et al., 2019).

While proper application of N, P, and K can significantly improve yields, improper use can lead to adverse effects (Pereira et al., 2019). However, no optimal water-soluble fertilizer formulation has yet been developed specifically for watermelon cultivation. To address this gap, it is necessary to determine the ideal fertilizer rates based on conventional NPK practices. This study was conducted to evaluate and identify the optimal water-soluble NPK rates for enhancing the growth, yield, and fruit quality of watermelon. The null hypothesis posits that different water-soluble NPK fertilizers have no effect on watermelon growth, while the alternative hypothesis suggests they do. The findings of this research serve as a proof of concept, contributing to the future development of efficient, cost-effective, and energy-saving water-soluble fertilizers for watermelon cultivation.

II. METHODOLOGY

A. Locations and Experimental Materials

This experiment was conducted in the rain shelter structure at Malaysia Agricultural Research and Development Institute, Sintok, Kedah (6.488305, 100.482) from June 2024 to August 2024. The planting materials used in this study was watermelon (Citrullus lanatus) var. 168 produced by Leckat Seed Company.

B. Treatments and Experimental Design

This experiment consisted of four water-soluble NPK rate treatments arranged in a randomized complete block design (RCBD) with seven replications. The replications used were represented as a block to reduce the errors and interferences in the field. Each of the replicates consisted of three plants, totalling to 84 plants. The rates or percentages of fertilizer treatments were calculated based on the actual rate of granular fertilizer (400kg N:P:K;15:15:15/hectare and 400kg N:P:K;12:12:17:2/hectare) used in common watermelon cultivation at open field planting system. Thus, the amount of NPK determined for the whole cultivation is equal to 108 kg N, 247.32 kg P and 153.6 kg K. The descriptions of the treatments used in this study were followed as table 1.0.

Table 1. *Application of different fertilizer rates compared to common fertilizer rate using single straight fertilizer*

FERTILIZER RATE TREATMENTS
T1 – 75% (25% less)
T2 (Control) – 100%
T3 – 125% (25% high)
T4 – 150% (50% high)

Treatment 2 (100%) was represented as control (108 kg N, 247.32 kg P and 153.6 kg K). The amount used for other treatments was calculated based on the control rate. Each of treatment solutions were prepared using three main fertilizer components as urea (N-46%), diammonium phosphate (N-16%; P2O5-45%) and muriate of potash (K2O-60%). Each of fertilizer components was calculated and mixed together with water in order to produce the water-soluble fertilizer treatments.

C. Plant maintenances and Treatment Application

Seeds were sown in a germination tray filled with 100% peat moss and placed under 25% shade. 14 days after sowing (DAS), the uniform-sized seedlings were selected and transplanted at the field. All the seedlings were daily watered using drip irrigation system. The amount of water supplied for each seedling were adjusted accordingly with the growth stage. The plants were then fertigated using water soluble fertilizer treatments by manual drenching at 100 mL/ seedlings. Application of the treatments was done at three growing stages of 2 and 10 (vegetative), 30 (flowering) and 45 (fruiting) days after transplanted (DAT). During the reproductive stage, assisted pollination was done from

0830 h to 1030 h. Male flowers were attached to female flowers with the ratio of flower used at 3:1; male: female to initiate the pollination process. Pollinated flowers were labelled with the date and time. At 65 DAT, the fruits were harvested for quality assessments. Pest and disease management was done when necessary, depending on the growing stages throughout the experiment.

D. Data collection

Growth measurements

Plants were randomly sampled from each treatment to determine the stem diameter, leaf area index (LAI) and leaf SPAD at 45 DAT. Stem diameter was measured at 3 cm above the ground using an electronic digital calliper (Model CD6''CS Mitutoyo Corp., Japan). To get leaf area index, leaf length and leaf width measurements were taken from a selected 5th leaf from shoot tip. Leaf length was measured beginning at the leaf blade-petiole intercept to the leaf tip. The leaf width was measured at the widest leaf lobes. Individual leaf area was then calculated from leaf length and leaf width, using the equation of Brantley and Young, (2007).

LA = -210.61 + 13.358 W + 0.5356 LW

L is the leaf length

W is the leaf width

From the LA, Leaf area index was calculated as:

$$LAI = \frac{\text{Leaf area}}{\text{Land area}}$$

Leaf SPAD was measured on the fully expanded leaves using leaf chlorophyll meter (SPAD-502 plus, Konica Minolta, Spectrum Technologies Incorporated, Plainfield, Illinois, USA). The measurements were taken from three different spot on the leaf surfaces.

Chlorophyll pigments

At 45 DAT, plants were selected at random from each treatment plot for leaf chlorophyll pigments determinations as chlorophyll a, b and total chlorophyll. Two plants samples were randomly selected and one fully expanded leaves from each plants. Samples were taken from the leaf using a single hole puncher at 5 mm diameter size. Pigments were extracted from ten leaf disks using dimethyl sulfoxide (DMSO). Leaf disks were then pipetted with 10 ml of DMSO and then incubated at 65 °C in an oven for 4 hours until all the pigments were extracted and the samples became transparent. Then, 3 ml aliquot of the green coloured was pipetted into the cuvette and 3 ml of DMSO was pipetted into another cuvette to serve as a blank. Samples were quantified using spectrophotometer (UV-Vis Spectrophotometer Optizen Pop) and were read at 649, 665, 480 and 510 nm under low light condition. Chlorophyll contents were calculated based on the following equations.

nmol (Chl a)/cm2 = [12.47 E665 – 3.62 E649) x V x 1.119]/A

nmol (Chl b)/cm2 = [25.06 E649 – 6.45 E665) x V x 1.102]/A

nmol (Chl a+b)/cm2 = (Chl a) + (Chl b)

Chlorophyll a, b and total chlorophyll were expressed as nmole/cm2 of fresh weight materials. At 65 DAT, the fruit were harvested and weighed using digital analytical balance for fruit weight parameter.

Yield and fruit quality

Yield and fruit quality components such as fruiting days, fruit weight, fruit circumference, pulp thickness and total soluble solid (TSS) were taken at 65 DAT. Fruiting days was counted from pollination day until harvesting day. Fruit weight from each plant was measured using digital analytical balance. Then, the fruit circumference was measured using measuring tape at the centre of the fruit. The juice for total soluble solid parameter was extracted and transferred into a digital refractometer (PR-100, Pallette, Atago Co., LTD., Japan) while the reading was taken in degrees Brix (Bxo).

E. Data collection

All the data taken was computed using statistical analysis software (SAS) version 9.4 (SAS Institute Inc., Cary, NC). GLM procedure was used to do analysis of variance and mean comparisons were calculated using Least Significant Difference (LSD) at P≤0.05.

III. RESULTS AND DISCUSSIONS

Table 2 showed the effect of fertilizer rates on growth components of watermelon as stem diameter, leaf area index and leaf SPAD. Both growth components such as stem diameter and leaf area index were significantly affected by fertilizer rate treatments. Fertilizer rates induced at 125% was significantly increased stem diameter of watermelon with 11.5%, 12.1% and 13.1% higher as compared to T1, T2 (Control) and T4 respectively. In addition, application of fertilizer rates at 125% was significantly increased the leaf area index with 10% and 15% higher than T1 and T2 (Control). On the other hand, no significant effect was observed between the application of fertilizer rates on leaf SPAD measurements.

Table 2: *Effect of various fertilizer rates on growth components of watermelon*

Treatments	Stem diameter	Leaf Area Index	Leaf SPAD
T1 - 75%	10.8b	618.8b	51.5
T2 - 100%	11.5b	634.1b	50.8
T3 - 125%	12.2a	765.9a	52.3
T4 - 150%	11.6b	658.4ab	50.6

Means with the different letters in each column indicate significant differences at 95% probability level according to LSD

Table 3 showed the effect of fertilizer rates on photosynthetic pigments of watermelon as chlorophyll a, b and total chlorophyll. As increased of fertilizer rates, both chlorophyll a and b were significantly increased. Fertilizer rate induced at 150% in chlorophyll a was significantly higher than 75% and 100% (Control) in 3.98% and 3.71% respectively. Similarly, fertilizer rate induced at 150% in chlorohyll b was significantly higher than 75% and 100% with the respective increments of 12.63% and 10.22%. On the other hand, no significant effect was observed between the application of fertilizer rates on total chlorophyll measurements.

Table 3: *Effect of various fertilizer rates on photosynthetic pigments of watermelon*

Treatments	Chlorophyll a	Chlorophyll b	Total chlorophyll
T1 - 75%	72.4b	32.5b	81.5
T2 - 100%	72.6b	33.4b	83.1
T3 - 125%	74.8ab	36.7ab	83.3
T4 - 150%	75.4a	37.2a	83.7

Means with the different letters in each column indicate significant differences at 95% probability level according to LSD

Table 4 showed the effect of various fertilizer rates on fruiting day, fruit circumference, fruit weight and TSS. As increased of fertilizer rates, were significantly increased the fruiting day, fruit weight and total soluble solid (TSS). In fruiting day parameter, application of fertilizer rates at T3-125% and T4-150% were significantly higher than T2-100% (Control) with 10.32% increments. Both fertilizer rates under T3-125% and T4-150% in fruit weight were significantly higher than T2-100% (Control) with the respective increments of 11.18% and 13.02%. As increased of fertilizer rates at T3-125% and T4-150% in TSS, were significantly increased the TSS value as compared to T2-100% (Control) at 11.71% and 12.5% respectively. On the other hand, no significant effect was observed between the application of fertilizer rates on fruit circumference measurements.

The application of fertilizer at the T3-125% rate significantly improved both stem diameter and leaf area index (LAI) in watermelon, as demonstrated by the results. Stem diameter is a key indicator of plant vigor and structural strength, which supports efficient transport of water, nutrients, and photosynthates.

Table 4: *Effect of various fertilizer rates on yield components of watermelon*

Treatments	Fruiting day	Fruit circumference	Fruit weight	TSS
T1 - 75%	31b	65.4	5.68b	9.6b
T2 - 100%	31.3b	65.6	5.88b	9.8b
T3 - 125%	34.9a	66.0	6.62a	11.1a
T4 - 150%	34.9a	69.2	6.76a	11.2a

Means with the different letters in each column indicate significant differences at 95% probability level according to LSD

The increase in stem diameter at the 125% fertilizer rate can be attributed to enhanced availability of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K), which are crucial for cell division, elongation, and overall plant development (Marschner, 2011). However, exceeding this optimal rate (T4-150%) may lead to nutrient imbalances or toxicity, potentially hindering stem growth. These findings are consistent with studies in other crops, where optimal fertilization has been shown to improve plant growth, while excessive application can reduce efficiency and cause environmental harm (Fan et al., 2008).

A higher LAI indicates greater photosynthetic capacity, which directly influences biomass production and fruit yield. The increased LAI at the 125% fertilizer rate is likely due to improved nutrient uptake, particularly nitrogen, a key component of chlorophyll and proteins involved in photosynthesis. This aligns with other studies showing that optimal fertilization enhances leaf expansion and canopy development, leading to better light interception and carbon assimilation (Liu et al., 2013). The observed increase in chlorophyll a and b at higher fertilizer rates (T4-150%) suggests that optimal fertilization boosts the photosynthetic potential of watermelon plants. Similar findings in crops like tomatoes, cucumbers, and melons have shown that increased fertilizer rates enhance chlorophyll concentration, which is linked to improved plant growth and higher yields (Zhang et al., 2015). This effect may result from better nutrient uptake, particularly nitrogen, which is essential for chlorophyll synthesis and photosynthetic enzyme activity (Liu et al., 2013).

The study also revealed that higher fertilizer rates, specifically at 125% and 150%, significantly improved watermelon quality parameters, including fruiting day, fruit weight, and total soluble solids (TSS). Fruiting day was notably earlier in T3-125% and T4-150%, consistent with studies showing that optimal nutrient application accelerates reproductive growth. Higher fertilizer rates facilitate quicker nutrient uptake, stimulating early flowering and fruit set, thereby extending the fruiting period. For instance, Maluki et al. (2016) reported that watermelon plants with nitrogen applied at 120 kg N/ha exhibited earlier flowering compared to lower rates. Additionally, the study found that increasing fertilizer rates significantly boosted fruit weight. Previous research has shown that applying NPK fertilizer at 50% above conventional levels increased watermelon yield by 69.2% (Awere & Onyeacholem, 2014). Similarly, studies on watermelon cultivars ‘Julie F1’ and ‘Sukari F1’ demonstrated that higher fruit weight and yield were achieved at 125% of the recommended NPK rate (Ndereyimana et al., 2021). The synergistic effects of nitrogen and phosphorus fertilization enhance photosynthesis, increasing carbohydrate production, which likely contributes to greater fruit weight at higher fertilizer rates. Potassium, facilitated by these nutrients, plays a critical role in translocating photosynthates to developing fruits (Maluki et al., 2015).

The significant increase in TSS suggests that phosphorus, in particular, positively influences the internal quality of watermelon. Higher phosphorus levels enhance photosynthesis and activate potassium uptake, which is responsible for transporting photosynthates from leaves (source) to fruits (sink) (Aguyoh et al., 2010). This improved transport results in higher-quality fruits with elevated TSS. These findings are supported by other studies, where higher phosphorus application rates led to increased TSS compared to untreated controls (Maluki et al., 2016).

IV. CONCLUSION

In summary, the study demonstrates that increasing fertilizer rates to 125% and 150% of the recommended dose significantly enhances growth components, chlorophyll pigmentation, yield, and fruit quality in watermelon. Among the two treatments evaluated, the application of 125% water-soluble NPK was identified as the most economically efficient fertilizer rate compared to 150%. Based on the findings of this study, a new fertilizer formulation has been developed, which is expected to be cost-effective due to its single straight fertilizer composition, making it suitable for integration into smart fertigation systems. Further trials on a commercial scale are recommended to validate the effectiveness of the new formulation in boosting watermelon yield and quality, as well as to proof the finding of this study.

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