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Development of Water Soluble NPK Fertilizer for Watermelon Cultivation Under Rain Shelter Structure

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ABSTRACT

Commercial watermelon cultivation at open field depends on granular fertilizer for higher yield and quality. However, application of granular fertilizer is laborious, inefficient, inadequate nutrient uptake and can cause toxicity. Therefore, smart fertigation system as incorporated by IoT (Internet of things) appears to be the best option to improve such issues. To complete the smart fertigation system, application of water-soluble NPK fertilizer is the key tool. Therefore, an experiment was conducted to evaluate and select the optimum water soluble NPK rates used on growth, yield and fruit quality of watermelon under rain shelter structure. 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 150% significantly increased leaf number, leaf SPAD, total leaf area and leaf dry weight as compared to control at 14.17%, 16.22%, 21.55% and 15.06% respectively. Whereas, application of fertilizer at 125% significantly increased the leaf number, total leaf area and leaf dry weight with the respective increments of 11.5%, 17.19% and 13.08%. Based on regression trendline, application of 125% optimized the performances of the plants such as leaf number, total leaf area and fruit weight. To conclude, increasing 25% NPK standard fertilizer rate (125%) could be promising for watermelon cultivation throughout fertigation under open field planting system. Further trials in open field planting system needs to be undertaken to ensure the selected rates identified from this study could improve the whole performances of watermelon.

Keywords: Watermelon, Fertigation System, Water Soluble Fertilizer, NPK Fertilizer

INTRODUCTION

Watermelon is an herbaceous creeper of the *Curcurbitaceae* plant family. It is also considered as a short-term horticulture crop that has more than 750 species and around 100 genera (Enujeke, 2013). It is commonly consumed across the world because it is high in nutrients such as phytonutrients and antioxidants such as lycopene (Reetu and Tomar, 2017). For a successfull watermelon cultivation, factors like fertilization plays an important role. Recently, the fertilization programme that has been developed for watermelon in Malaysia is highly dependable on granular fertilizer. However, this approach is laborious, time consuming, insufficient nutrient uptake due to erratic rainfall and can cause toxicity. The insufficient nutrient uptake contributed by the deficiency or inadequate soil nutrients for appropriate plant uptake resulted in poor growth and crop quality (Aluko et al., 2014). Apart from the economic concerns, excess fertilisation especially for nitrogen element have been linked to nitrate pollution of ground water bodies (Craswell, 2021) as well as an increase in pest and disease incidence (Gomez-Trejo et al., 2021). To address these issues, application of water-soluble fertilizer under fertigation system is a promising solution that can provide sufficient nutrient for plant absorption without wastage to the soil.

Fertigation is used extensively in commercial agriculture and horticultural crops. It is widely used in protected agriculture for water and fertiliser management, which can improve resource utilisation efficiency, increase crop yield and quality, reduce environmental pollution, and promote agricultural sustainability (Lin et al., 2020). Fertigation allows an accurate and uniform application of nutrients to the wetted area in the root zone, where the active roots are concentrated. In comparison with conventional fertilization approaches, drip fertigation has the advantages in promoting the use efficiencies of water and fertilizer and improving crop yield and quality (Ma et al., 2022). Previous study in apple has showed that, the application of drip fertigation had increase the yield of apple at 29.2%, titratable acidity at 4.9% and total soluble solid (TSS) at 5.3% (Kumar et al., 2016). It also promotes date palm yield by 41% and saves 66% of fertilizers (Al-Qurashi et al., 2016). Moreover, with a 25% to 50% reduction in N fertilizer, fertigation raises the leaf N and stem diameter of peach plants (Casamali et al., 2021). According to Ma et al. (2022), drip fertigation increased fruit output and total sugar content (TSS) by 9% and 8% while conserving 7% of fertilizer in Florida's citrus farms. In accordance with technology advancement, the Internet of Things (IoT) has numerous applications in the field of agriculture including fertigation systems. IoT has been widely used especially in precision agriculture. By using IoT, long-term profitability, more productivity and greater quality products can be achieved (Ruan et al., 2019). Incorporation of IoT will enable precise fertilization, sufficient nutrient uptake, as well as provide time and energy saving for watermelon cultivation under fertigation system (Ayaz et al., 2019).

In order to implement smart fertigation with IoT monitoring programme, the development of water-soluble NPK fertilizer is a key instrument that has become a requirement to complete the entire system. Water soluble fertilizers are used as chemical fertilizer in sprinkler or drip irrigation systems to boost production and quality of fruits and vegetables. These are generally combinations of nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and micronutrients in various ratios (Malhotra, 2016). One of the agricultural techniques for attaining higher watermelon yields is the application of optimum fertilization. The growth, development, and production of plants all depend on nitrogen (N), phosphorus (P) and potassium (K), all of which are in high demand in watermelon (Loka et al., 2019). Applying N, P, and K to watermelon can boost yields, but when done incorrectly, it can also have unfavorable effects (Pereira et al., 2019). Nevertheless, there is no optimum water-soluble fertilizer formulation has been developed for watermelon cultivation to this point in time. To identify the optimal water-soluble based for good plant performances in watermelon, there is a need to ascertain the optimal rates of fertilizer required based on conventional NPK fertilizer used in common cultural practices. This experiment was therefore conducted to evaluate and select the optimum water-soluble NPK rates on growth, yield and fruit quality of watermelon under rain shelter structure. The null hypothesis of this research is, there is no effect of different water-soluble NPK fertilizer on the growth of watermelon. While, the alternative hypothesis is, there is an effect of different water-soluble NPK fertilizer on the growth of watermelon. The finding of the research is proof of concept that may contribute to the future development of growing watermelon using optimum water-soluble based fertilizer that is efficient, time, cost and energy saving.

MATERIALS AND METHODS

Location 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 2022 to October 2022. The planting materials used in this study was watermelon (*Citrullus lanatus*) var. 168 produced by Leckat Seed Company.

Treatments and Experimental Design

This experiment consisted of four water-soluble NPK rate treatments arranged in a randomized complete block design (RCBD) with four replications. The replications used were represented as a block to reduce the errors and interferences in the rain shelter structure. Each of the replicates consisted of eight plants, totalling to 128 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%; P_2O_5-45%) and muriate of potash (K_2O-60%). Each of fertilizer components was calculated and mixed together with water in order to produce the water-soluble fertilizer treatments.

Plant Maintenances and Treatment Applications

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 into a 4 litres white polyethylene bags filled with 100% cocopeat. All the seedlings were daily watered using drip irrigation system. The amount of water supplied for each seedling were increased accordingly with the growth stage of watermelon. The plants were then fertigated using water soluble fertilizer treatments by manual drenching using small container at 100 ml/seedlings. Application of the treatments were done at three growing stages as 15 (Vegetative), 30 (Flowering) and 45 (Fruiting) days after transplanting (DAT). As the plant grew, excess water shoots were removed to increase the growth of the main shoot. The growing shoots were attached to a rope to support the plant's structure and facilitate maintenance. 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 the fruit setting stage, only one fruit per plant was maintained throughout this experiment, whereas the rest was removed. Growing fruits were supported with the rope to prevent abortion. As the fruit became bigger in size, the whole main stem of the plants was separated from the rope and put neatly on the ground. 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.

Data Collection

Growth Measurements

Plants were randomly sampled from each treatment to determine the plant height, stem diameter, leaf number, total leaf area, dry weight, and leaf SPAD at 55 DAT. Plant height was measured 3 cm above the ground to the highest shoot tip using a measuring tape. Scion diameter was measured at 3 cm above the ground using an electronic digital calliper (Model CD6"CS Mitutoyo Corp., Japan). Leaf number was manually counted and recorded based on fully expanded leaves. 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. The whole plants were then harvested and separated into leaves, stems and roots for total leaf area measurement and dry weight determination. Total leaf area was measured using automatic leaf area meter (LI-3100C, LI-COR, Lincoln, Nebraska, USA). While dry weight of each plant parts was determined using digital analytical balance (Mettler Toledo EL 204, Switzerland) after drying in an oven at 70 °C for 72 hours.

Yield and fruit quality

Yield and fruit quality components such as fruit weight, total soluble solid (TSS) and total titratable acidity (TTA) were taken at 65 DAT. Fruit weight from each plant was measured using digital analytical balance. Harvested fruit was then cut and the juice was extracted and transferred into a digital refractometer (PR-100, Pallette, Atago Co., LTD., Japan) while the reading was taken in degrees Brix (Bx^{o}). The TTA was quantified using a titrator instrument (Metrohm, Tiamo 848 Titrino plus, Germany). The value for TTA was expressed by citric acid that served as a major organic acid.

Data Analysis

All the data taken was computed using statistical analysis software (SAS) version 9.4 (SAS Institute Inc., Cary, NC). General Linear Method (GLM) procedure was used to do analysis of variance and mean comparisons were calculated using Tukey's Honest Significant Difference at $P \leq 0.05$. Relationships among the variables for fertilizer rate treatments were pooled and determined using Pearson correlation coefficients (r) at $P \leq 0.05$ by CORR (correlation command in SAS) procedure. Regression analyses were calculated between fertilizer rates with the selected variables measured at $P \leq 0.05$ by REG (regression command in SAS) procedure.

RESULTS AND DISCUSSION

Vegetative growth

Table 2 showed the effect of fertilizer rates on vegetative growth of watermelon as leaf number, leaf SPAD, total leaf area, leaf, stem and root dry weight. Among all vegetative growth measured, leaf number, leaf SPAD, total leaf area and leaf dry weight were significantly affected by fertilizer rate treatments. Fertilizer rates induced at 125% was significantly increased the leaf number, total leaf area and leaf dry weight with the respective increments of 11.5%, 17.19% and 13.08%. In addition, application of fertilizer rates at 150% was significantly increased the leaf number, leaf SPAD, total leaf area and leaf dry weight at 14.17%, 16.22%, 21.55% and 15.06%

respectively. On the other hand, no significant effect was observed between the application of fertilizer rates at 75% with control.

Table 2. Effect of fertilizer rates on vegetative growth of watermelon at 55 DAT

Treatments	Leaf Number	Leaf SPAD	Total Leaf Area (cm^2)	Leaf Dry Weight (g)	Stem Dry Weight (g)	Root Dry Weight (g)
T1 - 75%	15.0c	26.8ab	1550.79c	13.29b	7.93a	0.44a
T2 - 100% (Control)	17.08bc	24.8b	1630.52bc	13.82b	8.50a	0.45a
T3 – 125%	19.3ab	27.8ab	1969.09ab	15.9a	9.07a	0.47a
T4 – 150%	19.9a	29.6a	2078.49a	16.27a	8.97a	0.49a

Means with the different letters in each column indicate significant differences at P≤0.05% level according to Tukey's HSD

Yield and fruit quality

Table 3 showed the effect of fertilizer rates on yield and fruit quality of watermelon as fruit weight, pH, total soluble solid and total titratable acidity. Only fruit weight was significantly affected by fertilizer rate treatments. Application of fertilizer rates at 125% and 150% high were significantly increased the fruit weight at 12.21% and 16.98% respectively.

Table 3. Effect of fertilizer rates on fruit weight, total soluble solid and total titratable acidity of watermelon at 65 DAT

Treatments	Fruit Weight (g)	Total Soluble Solid (Bx°)	Total Titratable Acidity
T1 - 75%	1469.64b	9.28a	0.21a
T2 - 100% (Control)	1604.83b	9.19a	0.23a
T3 – 125%	1827.95a	9.03a	0.11a
T4 – 150%	1933.10a	9.0a	0.10a

Means with the different letters in each column indicate significant differences at P≤0.05% level according to Tukey's HSD

Table 4. Pearson's linear correlation coefficients (r) between fertilizer rates, growth parameters and fruit weight of watermelon

	Leaf Number	Total Leaf Area	Leaf Dry Weight	Fruit Weight
Fertilizer Rates	0.77**	0.63**	0.75**	0.86**

**Significant at P≤0.01

Increasing of growth measurements (leaf number, total leaf area and leaf dry weight) and fruit weight in both fertilizer rates at 125% and 150% is due to greater amount of macronutrient supplied. This is contributed by the high supplementation of macronutrient elements in water-soluble NPK fertilizer such as nitrogen, phosphorus and potassium that could increase the vegetative growth of watermelon. In general, these primary macronutrients play a vital role in plant growth and development, and their application may boost crop growth, yield, and quality (Tripathi et al., 2014). Nitrogen is the most essential nutrient for plants, that required for synthesis of different molecules and macromolecules (Singh, 2015). Phosphorus is plentiful in plant cell membranes as phosphate, where involves in the processes of energy transformations, genetic inheritance, protein synthesis and cell division (Gebreslassie and Demoz, 2016). While, potassium is essential in numerous physiological functions, including photosynthesis, enzyme activation, water relations, assimilates, transportation, as well as plant growth and development (Zlatev and Lidon 2013). Our result corresponded with the findings of Sabo et al. (2013), who discovered that applying 200 kg/ha NPK fertilizer or 75% more than normal practises, had the highest influence on growth components and yield of watermelon. Previous research in watermelon also showed that, application of NPK fertilizer at 50% higher than conventional rate had significantly increased the vine length and yield of watermelon at 25.72% and 69.2% (Awere and Onyeacholem, 2014). In addition, observation of different NPK fertilizer rates on two watermelon cultivars indicated that, higher fruit weight and fruit yield was obtained with 'Julie F1' and 'Sukari F1' under 125% of the recommendation rate (N:P:K; 90:60:60 kg ha^{-1}) (Ndereyimana et al., 2021). The synergistic impact of N and P fertilization toward improvement of photosynthesis, which forms carbohydrates, may account for larger fruit weight attained with higher fertilizer rates. Additionally, the two components facilitate the absorption of K element, which is necessary for photosynthates translocated from their site of synthesis to the fruits (Maluki et al., 2015).

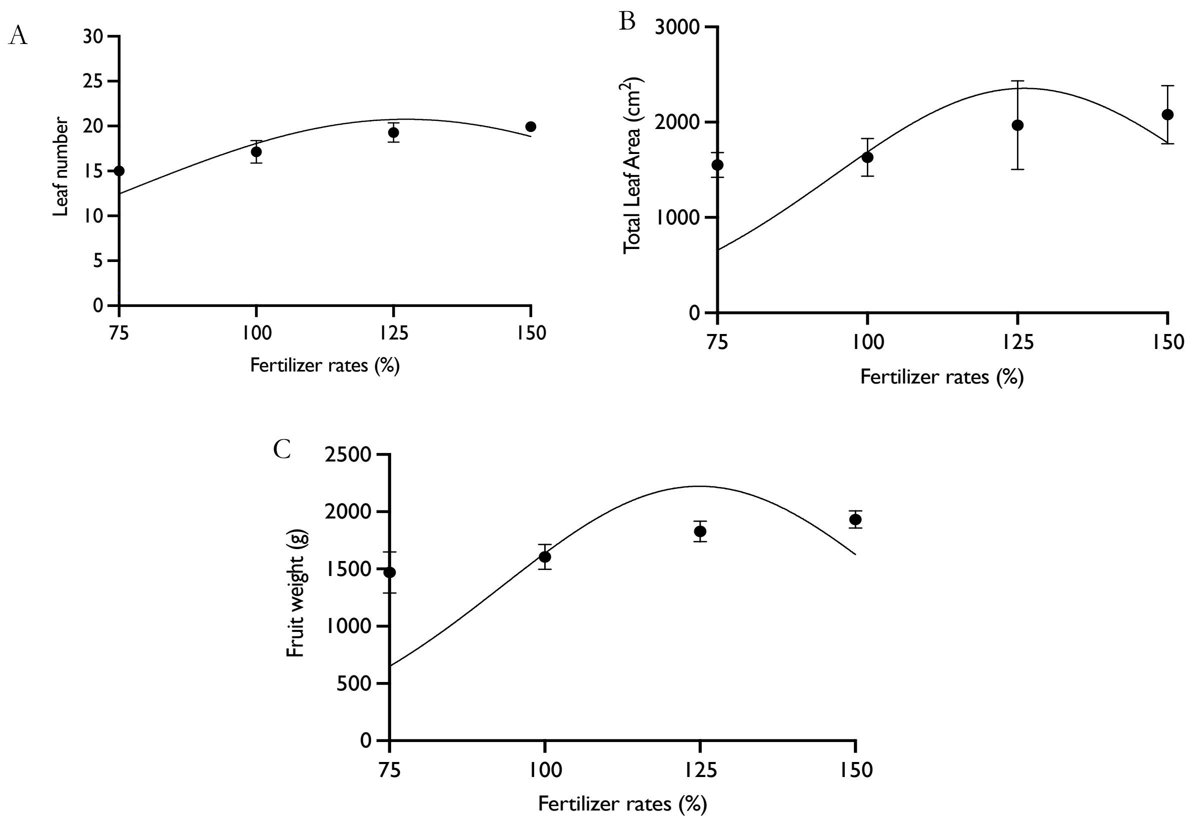

Fig 1. Regression analysis between fertilizer rates and selected parameters as leaf number (A), total leaf area (B) and fruit weight (C) of watermelon (Mean ± S.E.; n = 4)

Our result also consistent with the findings of Rolbiecki et al., (2020) who discovered that, supplementation of nitrogen fertiliser (liquid fertilization) through drip fertigation system had obtained the best performance cultivation in watermelon. Increment of fruit weight in our study was also corroborated with previous finding as fruit yield of watermelon had increased significantly with all level applications of N, P_2O_5 and K_2O due to water-soluble quality compared to control treatment (Kashyap et al., 2017). Highest leaf SPAD value at 150% fertilizer rates application, indicated the role of nitrogen elements that contributed for various metabolic process of energy transformation. According to the previous research, nitrogen is an essential ingredient of chlorophylls, which is directly related to the photosynthetic process (Nursu'aidah et al. 2014). Our result was also supported by correlation analysis (Table 4), the fertilizer rates was positively correlated with all significant parameters as ($r=0.77$; $P\leq0.01$), total leaf area ($r=0.63$; $P\leq0.01$), leaf dry weight ($r=0.75$; $P\leq0.01$) and fruit weight ($r=0.86$; $P\leq0.01$). This showed that, an increase of fertilizer rates was significantly increased selected growth parameters and fruit weight. According to Ndereyimana et al. (2014), N and P applications and watermelon production are positively correlated. In reality, P is a component of nucleic acids, nucleotides, sugar phosphates, phytic acid, and is recognized to play a significant part in the energy storage responses of plants.

In order to determine the optimum fertilizer rates for watermelon under rain shelter structure, regression analysis was performed in Figure 1 between fertilizer rates and selected significant parameters such as leaf number (1A), total leaf area (1B) and fruit weight (1C). The relationships showed that, the increment of NPK fertilizer rates was optimized at 125% for leaf number, total leaf area and fruit weight. This indicated the response rate of the plant towards growth and yield started to reduce as increased of fertilizer rate at 150%.

CONCLUSION

To sum up, application of water-soluble NPK fertilizer at 125% and 150% is capable to increase most of the growth parameters and yield of watermelon under rain shelter structure. Between both treatments identified, application of 125% water soluble NPK was selected as the optimum fertilizer rate to be adapted due to optimization level achieved in selected parameters measured as leaf number, total leaf area and fruit weight. Based on the rates determined from this study, a new formulation has been developed and is expected to improve growth and yield of watermelon in open field planting system in the future. The water-soluble fertilizer developed is low cost because the elements were prepared using single straight fertilizer and it is efficient since the application can be incorporated in smart fertigation system at the field. Further trials in open field planting system is recommended to be done to ensure the new formulation developed is suitable to boost watermelon yield and quality as well as to demonstrate the proof of concept from this study.

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