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Effect of Compost Mix of Mexican Sunflower (*Tithonia diversifolia*) Green Manure and Poultry Bone Meal on Productivity and Nutritional Quality of Red Russian Kale (*Brassicae napus* var. pabularia)

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Abstract. Mexican sunflower leaves (*Tithonia diversifolia*) contain high levels of nitrogen (N) and potassium (K). Combining it with poultry bone meal rich in phosphorus may produce a compost mix containing high N, P, and K. This research aims to compare the effect of this compost mix on the productivity and nutritional quality of Red Russian kale. The research was conducted at the Faculty of Agriculture and Business, Satya Wacana Christian University, from December 2023 to June 2024. Treatments tested were: CM-N_{100} (compost mix containing 100% of the required N); CM-P_{100} (compost mix containing 100% of the required P); CM-K_{100} (compost mix containing 100% of the required K); IF-NPK_{100} (inorganic fertilizer containing 100% of the required N, P, and K); and NPK_0 (zero fertilization). Plant height, number of leaves, crown diameter, biomass, harvest index, vitamin C, total anthocyanins, total chlorophyll, and carotenoids were measured then analyzed using the ANOVA test and Tukey-test ($P<0.05$). CM-P_{100} and CM-K_{100} (180-200 g of compost mix per pot) resulted in the highest yield, vitamin C, chlorophyll, and carotenoids. However, both treatments resulted in the lowest anthocyanins content. CM-N_{100} (95 g of compost mix per pot) resulted in the highest anthocyanin accumulation (92.84 mg/100 g). IF-NPK_{100} has supplied Red Russian kale with adequate N, P, and K but resulted in lower yield and nutritional quality compared to CM-P_{100} and CM-K_{100}. This indicated that higher nitrogen supply might still boost the productivity and nutritional content of Red Russian kale. Zero fertilization resulted in the least productive and nutritious kale leaves.

Keywords: anthocyanins; carotenoids; compost; Red Russian kale; vitamin C

INTRODUCTION

Kale is a precious vegetable that has been cultivated organically for niche market in the supermarket and e-commerce. Kale variants largely marketed in Indonesia are the curly type dan Lacinato/Nero. Both types can be consumed as raw vegetables (salad and smoothies) or cooked. Recently, there is a new type that has become well-known among farmers: Red Russian or Red Ruble kale. In Indonesia, this vegetable is suitable to be grown in high altitude (700-1300 m above sea level) as it requires the optimum temperature between 20-24˚C (Ligor & Buszewski, 2012). Despite of its emerging market, this kale variant has never been researched in Indonesia.

Kale generally contains higher amount of potassium and vitamin C compared to other vegetables. The Red Russian type per se is rich of carotenoid and anthocyanidins (Park et al., 2022). Carotenoids and anthocyanidins are responsible for the red and purple appearance of vegetables as well as highly beneficial for human health (Zhang & Jing, 2022). Organic production is an alternative to produce Red Russian kale nowadays in order to prevent harmful residues in agricultural produces. Organic production requires intensive use of organic materials as the source of nutrient. These can be animal waste, crop residue, green manure, domestic household waste, and other naturally available materials/rocks. Composting organic materials results in various essential nutrients necessary for plant growth. Nutrient content in raw organic materials is an important factor determining the quality of compost. Mixing various materials containing different essential macro and micro nutrients (nitrogen, phosphorus, potassium, etc.) will help produce complete nutrients and balanced nutrient proportion in compost. This leads to better plant growth (Samputri et al., 2023).

Previous research showed the increment of Lacinato kale when treated with solid compost of animal waste (especially poultry manure) containing as many N, P, and K as in synthetic fertilizer (Wijaya & Banjarnahor,

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2019). This indicates the contribution of other nutrients prevalent in solid compost which are absent in synthetic N, P, and K fertilizers. Application of liquid compost made of mixture of three organic materials (rabbit urine, milk, and eggs) produced higher kale yield compared to synthetic fertilizers or mixture of two organic materials containing equal N amount (Natanael & Banjarnahor, 2021). It was more interesting as the first mixture contained lower P and K content which led to the possibility of significant contribution of other nutrients present in the latter mixture. Those experiments have also shown nutrient supply are related to the accumulation of vitamin C, chlorophyll, and beta-carotene in kale.

The leaves of Mexican sunflower (*Tithonia diversifolia)* is a potential organic material for composting (Aboyeji, 2022; Opala, 2020; Setyowati et al., 2018) as it contains relatively high amount of nitrogen (N) and potassium (K) (Napitupulu *et al*., 2018): respectively 3.5% of N dan 4.1% of K. However, its phosphorus content was relatively low (0.37%) thus additional organic materials should be added to promote nutrient balance. One prominent source of phosphorus (P) is bone meal from poultry industry waste (Załuszniewska & Nogalska, 2022). This waste contains 13.2% of P (Mulyaningsih *et al*., 2013) thus is likely to increase phosphorus proportion when its bone meal is mixed with Mexican sunflower green manure. Mixing them together may help produce high-quality compost containing adequate and balanced macronutrients (N, P, and K). Application of this compost mix is expected to support organic vegetable production, one of which is the highly valuable Red Russian kale. Therefore, the aim of this research is to investigate the growth, yield, and quality of Red Russian kale when treated with different dosages of compost mix of Mexican sunflower green manure and poultry bone meal.

METHODS

The experiment was conducted in the greenhouse of the Faculty of Agriculture and Business of Satya Wacana Christian University (7°22'30.3"S 110°25'33.4"E) from December 2023 to April 2024. The experiment was arranged in a Randomized Completely Block Design using five treatments: 1) CM-N_{100} (compost mix containing 100% of the required N); 2) CM-P_{100} (compost mix containing 100% of the required P); 3) CM-K_{100} (compost mix containing 100% of the required K); 4) IF-NPK_{100} (inorganic fertilizer containing 100% of the required N, P, and K); and 5) NPK_0 (zero fertilization). Compost mix was made in two steps using 3 kg of dry Mexican sunflower leaves and 1 kg of dry poultry bone meal. First, the leaves of Mexican sunflower were cut into smaller pieces (1-2 cm) and composted in a closed bucket. Decomposers, sugar, and water were added into the bucket to trigger the process. This process was kept up to 2 weeks. Meanwhile, poultry bone meal was made by boiling poultry bones, drying them in an oven, and grinding them into dry powder. The solid compost and the dry bone meal powder were then mixed homogeneously. The nitrogen, phosphorus, and potassium content of this compost mix were then analyzed using standard methods.

This compost mix contained 5.2% of total N, 3.5% of P_2O_5, and 1.9% of K_2O. The recommended dose of nitrogen, phosphorus, and potassium for kale production was respectively 4.86 g, 7.01 g, and 3.52 g per plant (Wijaya & Banjarnahor, 2019; Yulianto & Zaman, 2017; and Qureshi, 2013). From the data of compost mix nutrient content and nutrient requirement, the amount of compost mix or synthetic fertilizer to be applied in each treatment were calculated. Since the nutrients in organic sources such as compost mix are binding to each other, changing the amount of a specific nutrient given to the plant will alter the dose of other nutrients (**Table 1**). Meanwhile, the required amount of nitrogen, phosphorus, and potassium can be provided separately when using inorganic fertilizer. Each treatment was replicated five times.

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Table 1. Details of each treatment given to Red Russian kale in this experiment

Treatment	Nutrient application	The estimated nutrient content (compared to kale nutrient requirement)
CM-N_{100}	94.2 g of compost mix per pot	**N (100%)**, P (46.9%), and K (51.1%)
CM-P_{100}	200.8 g of compost mix per pot	N (213%), **P (100%)**, and K (109%)
CM-K_{100}	184 g of compost mix per pot	N (195%), P (91.5%), and **K (100%)**
F-NPK_{100}	10.6 g of urea, 35 g of TSP, and 5,8 g of KCl per pot	N (100%), P (100%), and K (100%)
NPK_0	Without fertilization	-

For the pot experiment, 2–3-week-old Red Russian kale seedlings were used as planting materials. Each plant was grown in polybag and routinely watered to maintain soil moist and temperature. The recommended water amount for kale is 537 cc per plant (Chakwizira *et al*., 2013). Periodically, data of plant height, number of leaves, and crown diameter were recorded. Plants were harvested 50 days after transplanting, weighed immediately for measuring their fresh weight, dried in an oven (3 days, 80°C) and then weighed for its dry biomass.

Fresh leaves were analyzed to determine vitamin C, chlorophyll, carotenoid, and anthocyanin content. Vitamin C was measured using Iodine titration method. Chlorophylls and carotenoids were obtained from kale using DMSO method in which the absorbance was measured at 665, 649, and 480 nm. Anthocyanin content was determined using method proposed by Giusti & Wrolstad (1996). The absorbance was measured at 520 nm and 700 nm. Data were analyzed using the ANOVA test. Means were separated using Tukey-test at P<0.05.

RESULTS AND DISCUSSIONS

As shown in **Table 2**, compost mix doses significantly affected all parameters except the harvest index. These results indicated that the sufficiency of essential macro nutrient (N, P, and K) and nutrient sources (compost mix or synthetic fertilizer) strongly determine the growth, yield, and nutritional quality of Red Russian kale. Determining the appropriate nutrient amount and source is then necessary to support optimal production of Red Russian kale.

Table 2. Effects of different plant nutrient source on Red Russian kale

Parameters	Unit	F_{Count}	F_{Table}	
			5%	1%
Plant height	cm	79.129**	3.00	4.77
Number of leaves	-	65.714**	3.00	4.77
Crown diameter	cm	113.111**	3.00	4.77
Fresh weight of leaves	g	27.889**	3.00	4.77
Fresh weight of stem	g	12.75**	3.00	4.77
Fresh weight of roots	g	3.598*	3.00	4.77
Dry weight of leaves	g	25.185**	3.00	4.77
Dry weight of stem	g	3.838*	3.00	4.77
Dry weight of roots	g	14.847**	3.00	4.77
Harvest index	%	0.745ns	3.00	4.77
Vitamin C	mg/100g	101.644**	3.00	4.77
Total chlorophyll	mg/g	38.335**	3.00	4.77
Total carotenoid	mg/g	27.349**	3.00	4.77
Total anthocyanin	mg/100g	51.588**	3.00	4.77

Note: * = Significant at P<0.05, ** = Significant at P<0.01, ns = not significant.

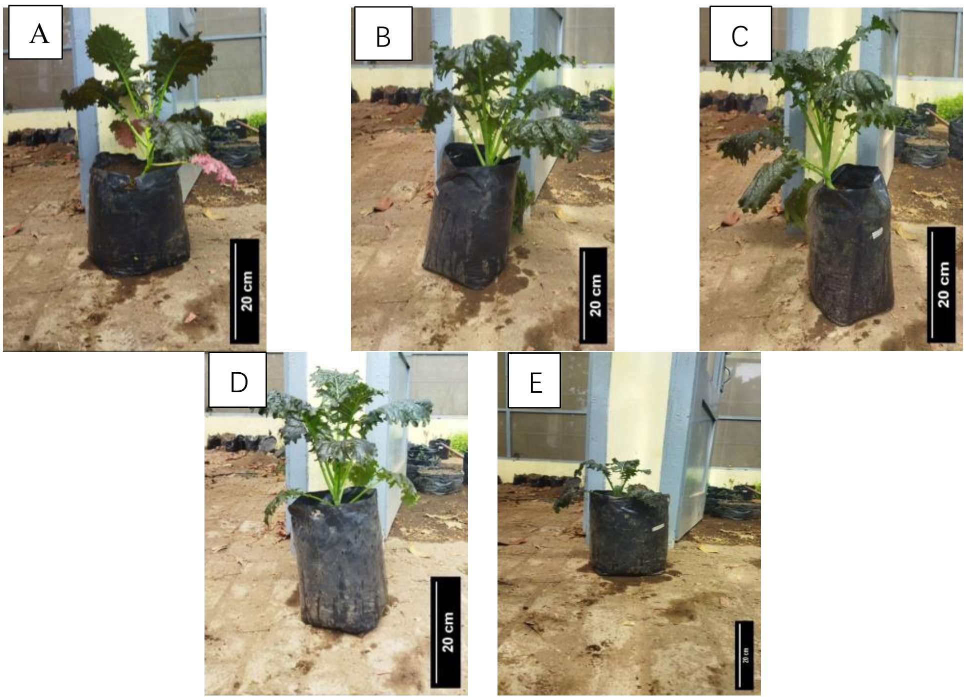

Figure 1. Plants appearance fifty days after transplanting in each treatment (A) CM-N_{100}, (B) CM-P_{100}, (C) CM-K_{100}, (D) F-NPK_{100}, (E) NPK_0.

As shown ini **Figure 1**, Red Russian kale plants supplied with additional nutrients be it from compost mix or synthetic fertilizer have grown bigger and taller than the plant without fertilization. Growing Red Russian kale without additional nutrients supply has significantly resulted in the lowest plant height, leaf number, and crown diameter (**Table 3**). Providing kale with compost mix using the dosage of 100% of recommended P and K (as in CM-P_{100} and CM-K_{100}) has automatically doubled the nitrogen supply as this nutrient is inherent in compost. Both treatments have significantly resulted in the highest plant stand, leaf number, and crown diameter. Providing kale with synthetic fertilizer using the dosage of 100% of recommended N, P, and K (F-NPK_{100}) was able to boost plant growth compared to zero fertilization. However, the effect is similar to the application of compost mix using the dosage of 100% of recommended N (CM-N_{100}). From this result, it can be inferred that the growth of kale could be significantly promoted by doubling the nitrogen supply while maintaining adequate phosphorus and potassium as well as providing other necessary nutrients (as contained in compost mix).

Table 3. The effect of different fertilizer treatments on the height, leaf number, and crown diameter of Red Russian kale

Treatments	Plant height (cm)	Number of leaves	Crown diameter (cm)
CM-N_{100}	28.48(b)	9.67(b)	33.00(c)
CM-P_{100}	33.06(c)	11.80(c)	35.06(c)
CM-K_{100}	32.08(c)	11.20(c)	33.52(c)
F-NPK_{100}	26.72(b)	9.40(b)	30.18(b)
NPK_0	21.18(a)	8.00(a)	19.54(a)

Note: Different letters in the same column indicate significant differences ($P<0.05$) based on Tukey-test.

Weekly plant growth parameters in each treatment were presented in **Figure 2**. The relatively faster growth of plants treated with CM-P_{100} and CM-K_{100} became more visible

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since week 3 and 4. In the following weeks, the different growth pace became even more obvious. This was due to the double supply of nitrogen from compost mix when P and K were given as recommended (CM-P_{100} and CM-K_{100}) as well as additional essential nutrients available in compost. Organic materials such as compost contain various essential nutrients which are binding to each other. Therefore, using a single nutrient supply (e.g., P only) as the baseline of fertilization recommendation will certainly influence the amount of other nutrients given to plants. Compost also contains micronutrients that help the vegetative and generative stages of growth (Purba *et al*., 2021). This is quite different from synthetic fertilizer, which contains limited types of nutrients (mostly N, P, and K) and thus cannot support balanced and complete essential nutrients needed for optimum growth.

Based on the growth of Red Russian kale under CM-P_{100} and CM-K_{100}, it was apparent this kind of kale has higher nitrogen sufficiency level than the recommendation. Sufficient essential nutrients during early growth will help leafy vegetable plants grow properly as they respond well to the availability of nutrients (Handayanto, *et al*., 2017). In this experiment, Red Russian kale responds to nutrients by elongating stem and plant crown as well as forming new leaves. This plant will even form new nodes and create what seems to be new branches. The more nodes and leaves formed during vegetative growth due to sufficient nutrients supply, the higher yield would be obtained by the end of growing season as the leaves are the main part of Red Russian kale to be harvested.

The absence of additional nutrient supply in Red Russian kale production has significantly resulted in the lowest yield (**Table 4**). Applying compost mix using the dosage of 100% of recommended P and K (CM-P_{100} and CM-K_{100}) have significantly resulted in the highest fresh and dry biomass. Providing kale with synthetic fertilizer using the dosage of 100% of recommended N, P, and K (F-NPK_{100}) was able to promote fresh and dry yield (leaves only) compared to zero fertilization. However, the effect is similar to the application of compost mix using the dosage of 100% of recommended N (CM-N_{100}). It can be concluded that Red Russian kale significantly accumulated biomass and leaf yield when the supply of nitrogen doubled and adequate phosphorus and potassium, as well as other necessary nutrients (as contained in compost mix), were provided. Nitrogen and phosphorus are instrumental to promote productivity (Bambang H & Santoso, 2018).

The increment of nutritional quality of Red Russian kale were found when additional nutrients were given in form of compost mix or synthetic fertilizer (**Table 5**). Providing 100% of the recommended nitrogen requirement (CM-N_{100} and F-NPK_{100}) has significantly promoted the amount of vitamin C, chlorophyll, and carotenoid in this vegetable. The highest amount of these three parameters was found in CM-P_{100} and CM-K_{100} in which P and K were applied sufficiently and nitrogen was supplied twice higher than recommendation.

This result signifies the importance of nitrogen on the accumulation of vitamin C, chlorophyll, and carotenoid in Red Russian kale. This study also confirms the positive relationship between K and vitamin C which is similar to the results reported by Kathi et al. (2023) where the increased application of potassium increased vitamin C in broccoli microgreens. Nitrogen and potassium are instrumental in vitamin C biosynthesis in which higher K supply will promote vitamin C content while excessive N could reduce it (Natanael & Banjarnahor, 2021). Therefore, fertilization may elevate vitamin C but seems to be less beneficial when given excessively (Boimau & Banjarnahor, 2023).

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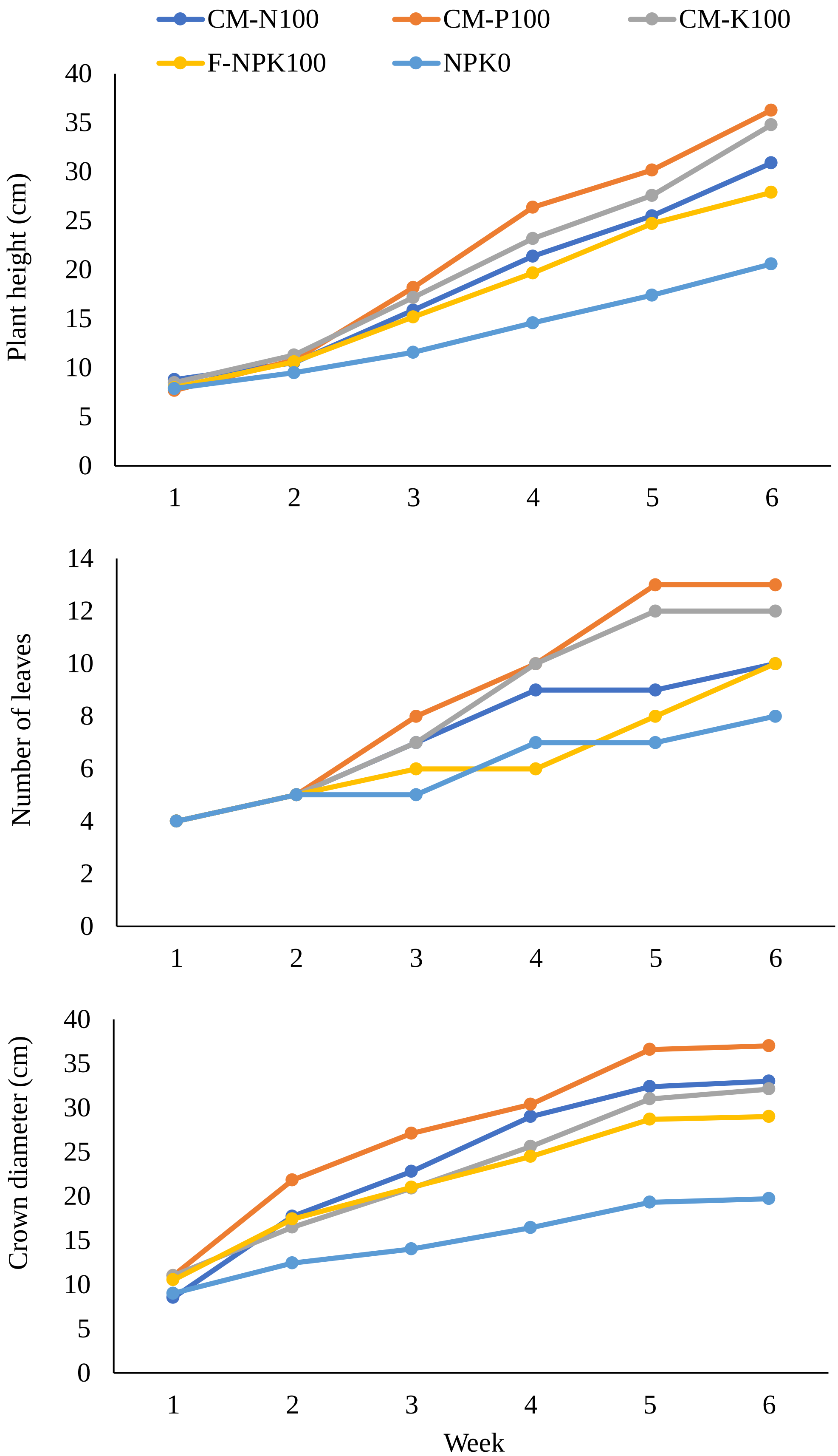

Figure 2. Weekly increment of plant height, number of leaves, and crown diameter in each treatment

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Table 4. The effect of different fertilizer treatments on fresh and dry biomass of Red Russian kale.

Treatments	Fresh weight (g)			Dry weight (g)			Harvest Index (%)
	Leaves	Stem	Roots	Leaves	Stem	Roots	
CM-N_{100}	66.97(b)	14.03(bc)	4.54(b)	5.10(b)	1.53(ab)	0.60(ab)	69.49(a)
CM-P_{100}	101.28(c)	21.41(c)	5.58(c)	7.92(c)	2.27(b)	0.94(bc)	79.98(a)
CM-K_{100}	97.57(c)	18.65(c)	6.40(c)	7.23(c)	1.91(ab)	1.02(c)	65.43(a)
F-NPK_{100}	61.37(b)	10.36(ab)	3.37(ab)	4.00(ab)	1.39(ab)	0.53(a)	68.95(a)
NPK_0	37.05(a)	6.14(a)	4.34(a)	3.25(a)	1.22(a)	0.29(a)	75.60(a)

Note: Different letters in the same column indicate significant differences (P<0.05) based on Tukey-test.

Table 5. The effect of different fertilizer treatments on nutritional quality of Red Russian kale

Treatments	Vitamin C (mg/100g)	Total Chlorophyll (mg/g)	Total Carotenoid (mg/g)	Total Anthocyanin (mg/100g)
CM-N_{100}	195.36(b)	398.93(b)	57.71(b)	92.84(d)
CM-P_{100}	244.64(d)	539.16(c)	76.59(c)	22.56(a)
CM-K_{100}	216.48(c)	565.93(c)	82.89(c)	34.23(ab)
F-NPK_{100}	188.32(b)	371.90(b)	52.78(ab)	62.00(c)
NPK_0	147.84(a)	254.78(a)	38.61(a)	46.74(bc)

Note: Different letters in the same column indicate significant differences (P<0.05) based on Tukey-test.

Conversely, anthocyanin in leaves lowered down prominently when nitrogen doubled (as found in CM-P_{100} and CM-K_{100}). Anthocyanins are natural pigments related to the red, purple, and blue colours of *Brassicaceae* vegetables and are regarded as beneficial for health. However, the production of anthocyanin in Red Russian kale reached peak when nutrient supply was relatively low (Park et al., 2022). While adequate supply of nitrogen and phosphorus promoted chlorophyll production in plants, this benefit might not help in the synthesis of anthocyanin as they both contradicted each other. Therefore, it is important to prioritize the nutritional benefits to be gained from Red Russian kale before deciding the most feasible fertilization source and dose. In future studies, the optimum dosage of essential macronutrients (especially N, P, and K) could be investigated in order to obtain the highest various nutritional benefits of Red Russian kale leaves.

CONCLUSIONS

Compost mix doses significantly affected all parameters except the harvest index. CM-P_{100} and CM-K_{100} treatments resulted in the best growth and productivity as well as the highest content of vitamin C, chlorophyll, and carotenoids. However, they both significantly reduced anthocyanins synthesis in Red Russian kale leaves. CM-N_{100} treatment resulted in the highest total anthocyanin (92.84 mg/100g) in kale. Zero fertilization resulted in the least productive and least nutritious kale. Despite of adequate NPK supply in IF-NPK_{100}, this treatment produced less productive and less nutritious yield compared to CM-P_{100} and CM-K_{100}. This was likely due to the fewer N supply in IF-NPK_{100} thus indicating that doubling N supply could boost the productivity and nutritional quality of Red Russian kale. Since Red Russian kale still produced higher yield and better quality when nitrogen supply was doubled under CM-P_{100} and CM-K_{100}, there is a room for further investigation on optimum nitrogen supply for promoting yield

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and nutritional quality of Red Russian kale especially using different organic sources.

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