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Yield response of watermelon (*Citrullus lanatus* Thunb.) cultivars to varied fertilizer rates in Rwanda

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Abstract

The choice of cultivar and adequate nutrition are vital for good watermelon (*Citrullus lanatus*) production. This study evaluated the yield performance of four watermelon cultivars: 'Sugar Baby', 'Crimson Sweet', 'Sukari F1' and 'Julie F1' under four different NPK fertilizer rates: 50, 75, 100 and 125 % of the recommended dose (RD) (90:60:60 kg ha^{-1} of Nitrogen (N): Phosphorus (P): Potassium (K). The experiment was laid out in a split-plot design, with cultivars in the main plots, fertilizer in the subplots and three replications. The experiment was conducted in two seasons: 2017A and 2017B at two sites; Karama and Rubona. A higher number of fruits per plant (5.1-5.8) was obtained with 'Julie F1' + 75 or 100 % of RD at both sites and in both seasons, followed by 'Sukari F1' + 100 % of RD and the open-pollinated cultivar A higher fruit weight (4.4-5 kg) was obtained with 'Julie F1' and 'Sukari F1' under 125 % of the RD. Plots planted with 'Julie F1' and treated with 75 % or 100 % of RD recorded higher fruit yield per plant (20.9-27.5 kg) and higher fruit yield per ha (104.2-137.3 t). From these results, it can be concluded that the high yield performance of watermelon in the study area can be obtained with 'Julie F1' using 75 % (67.5: 45: 45 kg ha^{-1}) of the recommended dose of NPK fertilizer.

Key words: Watermelon cultivars, F1 hybrid, nitrogen, phosphorus, potassium

Introduction

Watermelon (*Citrullus lanatus* Thunb.) is among the leading crops worldwide within the family *Cucurbitaceae,* which includes other crops such as squash (*Cucurbita moschata* Duch), cucumber (*C. sativus* L.) and melon (*C. melo* L.) (Santos *et al.,* 2009; Dube *et al.,* 2020). Its fruits are rich in vitamins C and A, and in compounds that prevent the risks of cancer, diabetes, kidney stone formation, and cardio-vascular diseases, among others (Sabo *et al*., 2013; Naz *et al.*, 2014). They also contain vitamin B and minerals such as iron, zinc, potassium, magnesium, manganese, phosphorus, and sodium (Oga and Umekwe, 2015). In Rwanda, watermelon is a new crop that started being cultivated after 1994 (Habimana *et al.*, 2014). This crop is a prospective source of income for smallholder farmers, who constitute the majority of the Rwandan agriculture sector.

The use of improved varieties and optimum fertilization are among the production technologies for achieving increased watermelon production (Sabo *et al.,* 2013; Loka *et al.,* 2019). Due attention given to these aspects is a key factor in improving production and increasing the benefit to producers (Pereira *et al.*, 2019). Varietal differences play an important role in the determination of crop growth and yield (Enujeke, 2013). It is recognized that cultivars respond differently to different agro-ecologies (Gishimu *et al.,* 2010). Thus, to find the most promising cultivar for a given agro-ecology, it is important to carry out adaptability trials to determine the performance of available cultivars. Rational use of fertilizer is an important factor in boosting the yield of any crop (Dube *et al.,* 2020). Watermelon has a high demand for nitrogen (N), phosphorus (P), and potassium (K), all of which are required for plant growth, development and yield (Santos *et al*., 2009). On one hand, the N, P and K applied to watermelon may increase the yield, while, on the other hand, they may cause unpleasant results when they are misused (Santos *et al.,* 2009; Pereira *et al.,* 2019). Since fertilizer is a significant cost input, effort is required to optimize its utilization in watermelon to ensure good production and economic returns.

Despite its nutritional value and income potential, watermelon production in Rwanda is still challenged mainly by poor agronomic practices, which lead to unpleasant yields (Clay and Turatsinze, 2014; Habimana *et al.,* 2014). In addition, limited research has been conducted on watermelon in Rwanda and, therefore, there is scarce information on its production technologies. More specifically, there is no precise information that has been generated on the performance of different varieties/hybrids commercialized in Rwanda and their optimum fertilizer requirements, among others. Moreover, Dube *et al.* (2020) emphasized the necessity to conduct investigations on the performance of watermelon varieties under different production technologies and environments.

The objective of this study was to determine the yield response of watermelon cultivars to varied fertilizer rates in Rwanda. The alternative hypothesis tested was that the yield of watermelon is affected by the cultivar and the fertilizer.

Materials and methods

Study sites and period: This study was conducted in two experimental sites of Rwanda Agriculture and Animal Resources Development Board (RAB), which are Karama and Rubona. Karama site falls in the driest agro-climatic region of Rwanda and is located in Eastern Province, Bugesera District, on longitude 02°23'15"S, latitude 30°11'27"E, and at an altitude of 1524 m above sea level. The soil, dominated by oxisols, is sandy loam with pH of around 6.0. The average annual rainfall and temperature are 854 mm and 21.4 °C, respectively (Kabirigi *et al.,* 2017). Rubona site is located in Southern Province, Huye District, on latitude 02°29'327"S, longitude 029°46'475"E, and at an altitude of 1727 m above sea level. The soil is sandy clay with pH of around 5.8. The average annual rainfall and temperature are 1039 mm and 19 °C, respectively (Ndabamenye *et al.,* 2013). In both sites, the study was conducted in two cropping seasons: 2017A (short rain season) covering the period from September through December 2016 and 2017B (long rain season) from February to May 2017.

Treatments and experimental design: Two factors were considered in this study. Factor one was cultivar with four levels: 'Sugar Baby', 'Crimson Sweet', 'Sukari F1' and 'Julie F1'. Factor two was fertilizer rate (F) with four levels: F1 = 50 % of recommended dose (RD) of N:P:K, F2 = 75 % of RD, F3 = 100 % of RD (90:60:60 kg ha^{-1}), and F4 = 125 % of RD. Split-plot embedded in a randomised complete block design with three replications was adopted with cultivar factor in main plots and fertilizer factor in subplots.

Trial establishment and maintenance: In each site, the field was ploughed twice at interval of 15 days prior to experimental layout. The field was then divided into three equal blocks; each block consisted of four main plots (24 x 3 m each) subdivided into subplots of 6 x 3 m each. Prior to transplanting, mulching was carried out using dry grass. Watermelon seedlings were raised in bio-degradable plastic pots and were transplanted 30 days after sowing. Before transplanting, holes measuring 30 cm^3 were made at a spacing of 2 x 1 m and refilled with 5 kg of well-decomposed cow manure mixed with topsoil. The tested fertilizer rates of N, P, and K for each treatment were applied using two commercial fertilizers NPK 17-17-17 and urea 46 % N. Based on the treatments, the amount of each commercial fertilizer used is provided in Table 1. The calculated amount of the fertilizer NPK 17-17-17 was applied to the crop in two equal splits: one at transplanting and the other at one month after transplanting while the whole amount of urea 46 % N was applied two months after transplanting. Fungicides (copper oxchloride and carbendazim) and insecticides (Lambda-Cyhalothrin and imidacloprid) were applied to control pests and diseases when necessary. Other cultural practices, such as watering and weeding were carried out conventionally.

Table 1. Amount of commercial fertilizers used per each treatment in the experiment

Fertilizer (nutrient) rates	Commercial fertilizers used	
	NPK 17-17-17 (kg ha^{-1})	Urea 46 % (kg ha^{-1})
50 % of RD* (45:30:30 kg ha^{-1} N:P:K)	176.5	32.5
75 % of RD (67.5: 45: 45 kg ha^{-1} N:P:K)	265	49
100 % of RD (90: 60: 60 kg ha^{-1} N:P:K)	353	65
125 % of RD (112.5: 75: 75 kg ha^{-1} N:P:K)	441	81

* RD: Recommended dose of N: P: K, N: Nitrogen, P: Phosphorus, K: Potassium

Data collection and analysis: Four plants were selected in each subplot and used for data collection on the number of fruits per plant, fruit weight (kg), fruit yield per plant (kg) and fruit yield per hectare (t). The number of fruits per plant was recorded by counting all fruits harvested on four selected plants per subplot and computing the average per plant. Fruit weight (kg) was obtained as the average from five mature fruits sampled randomly from the four selected plants in each subplot. Fruit yield per plant (kg) was calculated as the average of yield obtained from four selected plants per subplot. Fruit yield per hectare (t) was obtained by extrapolating to one hectare the fruit yield per plant. All the recorded data were subjected to analysis of variance (ANOVA) using Genstat® software package (20th Edition) and the level of significance was set at $P < 0.05$. Least significant difference (LSD) test was conducted for pair-wise comparisons of significantly different means.

Results and discussion

The yield parameters were significantly ($P < 0.05$) influenced by the studied cultivars and the fertilizer rates (Table 2 and 3); this agrees with the alternative hypothesis stated at the beginning of this study that yield of watermelon is affected by cultivar and fertilizer rate. Since interaction was significant, it means that the factors (cultivar and fertilizer) were not acting independently of one another (Rangaswamy, 2013). This implies that the yield of watermelon cultivars was influenced by the varied fertilizer rates. Thus, not only the choice of good cultivar but also adequate fertilization is equally important to ensure good watermelon yield (Dube *et al.,* 2020).

A higher number of fruits per plant (5.1-5.8) was obtained in plots where 'Julie F1' received an application of 75 and 100 % of RD which were not significantly different ($P > 0.05$) from one another at both Karama and Huye sites and in both seasons, 2017A and 2017B. 'Julie F1' was followed by 'Sukari F1' fertilized with 100 % of RD, which recorded 4.7-5.3 fruits per plant. The open-pollinated cultivars 'Sugar Baby' and 'Crimson Sweet' yielded a lower number of fruits per plant as compared to the hybrids ('Julie F1' and 'Sukari F1'). Fertilization of the open-pollinated cultivars with 100 % of RD recorded higher number of fruits per plant (4.1-5.1) at both sites and in both seasons (Tables 2 and 3). In accordance with the results of the current study, other studies also reported higher number of fruits per plant in watermelon hybrids as compared to open-pollinated cultivars (Mohanta and Mandal, 2019). This could be associated with heterosis (hybrid vigour) phenomena due to which the performance of hybrids is expected to be higher than open-pollinated cultivars including even the parents (Birchler *et al*., 2010; Dube *et al*., 2020). Higher numbers of fruits per plant recorded at 75 and 100 % of RD agree with Maluki *et al.* (2015) who reported this as a result of a reduced ratio of male to female flowers, triggered by the synergistic action between N and P where the former increases availability of the latter. On the other side, K promotes flower retention, leading

Table 2. Yield parameters of watermelon as affected by cultivar and fertilizer at Karama site

Treatments		Number of fruits per plant		Fruit weight (kg)		Fruit yield (kg plant^{-1})		Fruit yield (t ha^{-1})	
Cultivar	Fertilizer	Season 2017A	Season 2017B	Season 2017A	Season 2017B	Season 2017A	Season 2017B	Season 2017A	Season 2017B
Sugar Baby	50 % of RD	3.3 d	3.5 d	3.2 g	3.2 hi	10.5 f	11.1 f	52.6 f	55.5 f
	75 % of RD	4.3 c	4.5 c	3.7 f	3.7 fg	16.0 cde	16.9 de	80.2 cde	84.6 de
	100 % of RD	4.9 b	5.1 b	4.2 cd	4.2 cd	20.4 b	21.5 b	102.0 b	107.5 b
	125 % of RD	3.3 d	3.5 d	4.4 bc	4.5 bc	14.8 e	15.6 e	74.0 e	78.0 e
Crimson Sweet	50 % of RD	3.3 d	3.5 d	2.9 h	2.9 i	9.5 f	10.0 f	47.3 f	49.9 f
	75 % of RD	4.4 c	4.6 c	3.4 g	3.4 gh	15.0de	15.8 e	74.8 de	78.9 e
	100 % of RD	4.4 c	4.6 c	4.1 de	4.1 de	18.0 c	18.9 c	89.8 c	94.6 c
	125 % of RD	3.3 d	3.5 d	4.3 cd	4.4 cd	14.4 e	15.2 e	71.9 e	75.8 e
Sukari F1	50 % of RD	4.4 c	4.6 c	3.4 g	3.4 gh	15.0 de	15.8 e	74.8 de	78.9 e
	75 % of RD	4.4 c	4.6 c	3.8 ef	3.8 ef	16.8 cd	17.8 cd	84.1 cd	88.8 cd
	100 % of RD	5.1 b	5.3 b	4.4 c	4.4 c	22.2 b	23.4 b	110.8 b	116.9 b
	125 % of RD	4.3 c	4.5 c	4.7 ab	4.8 ab	20.5 b	21.6 b	102.4 b	107.9 b
Julie F1	50 % of RD	4.4 c	4.6 c	3.8 ef	3.9 ef	17.0 c	17.9 cd	85.0 c	89.7 cd
	75 % of RD	5.5 a	5.8 a	4.4 c	4.5 bc	24.4 a	25.7 a	121.8 a	128.5 a
	100 % of RD	5.5 a	5.8 a	4.7 b	4.8 ab	26.0 a	27.5 a	130.1 a	137.3 a
	125 % of RD	4.4 c	4.63 c	5.0 a	5.0 a	22.07 b	23.3 b	110.4 b	116.5 b
Significance		***	***	*	*	***	***	***	***
LSD ($P < 0.05$)		0.11	0.11	0.17	0.17	1.1	1.04	5.48	5.2

Mean values followed by the same letter(s) within the column are not significantly different at 5 % level of Least Significant Difference (LSD) test. RD: Recommended dose of N:P:K (90:60:60 kg/ha); * significance at $P < 0.05$, *** significance at $P < 0.001$

Table 3. Yield parameters of watermelon as affected by cultivar and fertilizer at Rubona site

Treatments		Number of fruits per plant		Fruit weight (kg)		Fruit yield (kg plant^{-1})		Fruit yield (t ha^{-1})	
Cultivar	Fertilizer	Season 2017A	Season 2017B	Season 2017A	Season 2017B	Season 2017A	Season 2017B	Season 2017A	Season 2017B
Sugar Baby	50 % of RD	3.1 d	3.4 d	2.9 g	3.2 g	9.0 f	10.8 g	45.0 f	54.0 g
	75 % of RD	4.0 c	4.4 c	3.4 f	3.7 f	13.7 cde	16.5 def	68.6 cde	82.4 def
	100 % of RD	4.5 b	5.0 b	3.9 cd	4.2 cd	17.5 b	21.0 b	87.3 b	104.8 b
	125 % of RD	3.1 d	3.4 d	4.1 bc	4.5 bc	12.7 e	15.2 f	63.3 e	76.0 f
Crimson Sweet	50 % of RD	3.1 d	3.4 d	2.7 h	2.9 h	8.1 f	9.7 g	40.5 f	48.6 g
	75 % of RD	4.1 c	4.5 c	3.1 g	3.4 g	12.8 de	15.4 ef	64.0 de	76.9 ef
	100 % of RD	4.1 c	4.5 c	3.8 de	4.1 de	15.4 c	18.4 c	76.8 c	92.2 c
	125 % of RD	3.1 d	3.4 d	4.0 cd	4.4 cd	12.3 e	14.8 f	61.5 e	73.9 f
Sukari F1	50 % of RD	4.1 c	4.5 c	3.1 g	3.4 g	12.8 de	15.4 ef	64.0 de	76.9 ef
	75 % of RD	4.1 c	4.5 c	3.5 ef	3.8 ef	14.4 cd	17.3 cde	72.0 cd	86.5 cde
	100 % of RD	4.7 b	5.2 b	4.1 c	4.4 c	19.0 b	22.8 b	94.8 b	113.9 b
	125 % of RD	4.0 c	4.4 c	4.4 ab	4.7 ab	17.5 b	21.0 b	87.6 b	105.1 b
Julie F1	50 % of RD	4.1 c	4.5 c	3.6 ef	3.9 ef	14.5 c	17.5 cd	72.7 c	87.3 cd
	75 % of RD	5.1 a	5.7 a	4.1 c	4.4 c	20.9 a	25.0 a	104.2a	125.2 a
	100 % of RD	5.1 a	5.7 a	4.4 b	4.7 ab	22.3 a	26.8 a	111.4 a	133.8 a
	125 % of RD	4.1 c	4.5 c	4.6 a	5.0 a	18.9 b	22.7 b	94.4 b	113.4 b
Significance		***	***	*	*	***	***	***	***
LSD ($P < 0.05$)		0.1	0.11	0.16	0.18	0.94	1.08	4.69	5.41

Mean values followed by the same letter(s) within the column are not significantly different at 5 % level of Least Significant Difference (LSD) test. RD: Recommended dose of N:P:K (90:60:60 kg/ha); * significance at $P < 0.05$, *** significance at $P < 0.001$

to more fruit set (Loka *et al.,* 2019). Rolbiecki *et al*. (2011) also obtained an increase in the number of watermelon fruits per plant with application of fertilizers supplying N, P, and K at the rates of 120, 100, and 150 kg ha^{-1}, respectively.

Regarding fruit weight, the evaluated hybrids had heavier fruits than the open-pollinated cultivars. Higher fruit weight (4.4-5 kg) was obtained with 'Julie F1' and 'Sukari F1' that were fertilized with 125 % of RD but it was not significantly different ($P > 0.05$) from 'Julie F1' under 100 % of RD in season 2017A at Karama site or from each of the two hybrids when fertilized with 100 % of RD at Rubona site in both seasons (Table 2 and 3). This agrees with earlier findings that watermelon responds positively to fertilizer application (Sabo *et al.,* 2013). In agreement with the findings of the current study, Saeed (2019) obtained a fruit weight of 5.0 kg with the watermelon hybrid Jumbo. Loka *et al.* (2019) also reported higher fruit weight with hybrids as compared to open-pollinated cultivars. This could be associated with the genetic makeup of these hybrids by which they are more responsive to applied fertilizer; which implies that fertilizer use efficiency is higher in the studied watermelon hybrids than the open-pollinated cultivars (Birchler *et al.,* 2010; Dube *et al.,* 2020). Similarly, Iken and Anusa (2004) stated that the potential yield of hybrids is usually high to attract the attention of farmers. Enujeke (2013) emphasized that crop yield is associated with the genetic makeup of a particular genotype and plant nutrition. Thus, cultivar selection and adequate nutrition are crucial for better watermelon yield. Higher fruit weight obtained with higher fertilizer rates may be explained by the synergism action of N and P toward enhanced photosynthesis through which carbohydrates are formed. The two elements also support the uptake of K which is involved in translocation of photosynthates from the site of their synthesis to the fruits (Maluki *et al.,* 2015).

For fruit yield per plant, higher fruit yield per plant (20.9-27.5 kg $plant^{-1}$) was obtained with Julie F1 applied with either 75 % of RD or 100 % of RD in both seasons and at both sites (Table 2 and 3). The performance of 'Julie F1' was followed by 'Sukari F1' fertilized with 100 % of RD which was not significantly different ($P > 0.05$) from 125 % of RD and 'Sugar Baby' fertilized with 100 % RD. Fruit yield per plant is a product of number of fruits per plant and fruit weight. Fruit yield per hectare (t) followed a similar trend as the fruit yield per plant (kg); higher fruit yield ranging from 104.2 to 137.3 t/ha was recorded with 'Julie F1' under 75 % of RD and 100 % of RD which were not significantly different ($P > 0.05$) (Table 2 and 3). Saeed (2019) also obtained a fruit yield of 102.4 t ha^{-1} with the watermelon hybrid Jumbo; which is in range with results of the present study.

Nitrogen is a major factor affecting watermelon yield (Goreta *et al*., 2005). It stimulates vegetative growth, which results in higher surface area of leaves, more chlorophyll, higher stomata conductance, and thus enhanced photosynthesis and translocation of photosynthates to the sinks (Maluki *et al.,* 2015; Larbat *et al.,* 2016; Maluki *et al.,* 2016). Besides, N functions as a constituent of amino acids, proteins, amides, nucleotides, nucleic acids, and coenzymes among others (Gent and Forde, 2017). This could be the reason why higher fruit weight and fruit yield were obtained in treatment combinations with higher N rates such as 75, 100 and 125 % of RD. In their study, Araújo *et al.* (2011) reported an increased watermelon yield with increase in N level while Goreta *et al.* (2005) did not observe any yield increase beyond the N rate of 115 kg ha^{-1}. On the other hand, Santos *et al.* (2009) observed increased severity of diseases with application of higher amount of N on watermelon. Therefore, attention should be taken when increasing any fertilizer level because unexpected negative effects may arise. From their study, Souza *et al.* (2014) reported a positive correlation between watermelon yield and N and P applications. In fact, P is known to play a major role in energy storage reactions of plants and is a component of nucleic acids, nucleotides, sugar phosphates, and phytic acid among others. Phosphorus and nitrogen together are among the factors limiting crop productivity (Raven, 2018). In accordance with results of the current study, Oliveira *et al.* (2012) obtained a positive effect of K application on watermelon yield. This could be attributed to the fact that K is used as a co-factor for more than 40 enzymes and is a principal cation involved in establishing cell turgor leading to cell expansion, stomata aperture, and maintaining electro-neutrality (Ragel *et al.,* 2019). In their study, Oga and Umekwe (2015) observed that NPK fertilizer significantly affected watermelon yield.

The findings of this study are in agreement with Pereira *et al.* (2019) who reported that proper variety selection and adequate fertilization are important factors to ensure good production of a particular crop. Since with 'Julie F1', there was no significant difference in fruit yield obtained under 75 and 100 % of RD, it is obvious that farmers should consider using 75 % of RD, which will cut on the cost of production and ensure higher net benefit as compared to use of 100 % of RD. For farmers, who consider that hybrid seed is expensive and would like to use open-pollinated cultivars seed, this study recommends to use 'Sugar Baby' and fertilize with 100 % of RD (90:60:60 kg ha^{-1}).

The present study looked at the rate of fertilizer to be applied on watermelon crop, which is a small portion considering the package of fertilizer recommendations that should include other aspects such as fertilizer type used as source of nutrients, time of application, and method of application among others (Hochmuth and Hanlon, 2010). Thus, further studies should be conducted not only to validate, but also to complement the current study.

From the results of this study, it can be concluded that high yield performance of watermelon in the study area can be achieved with the cultivation of 'Julie F1' using 75 % of the recommended dose of NPK fertilizer which is 67.5: 45: 45 kg/ha [(265 kg ha^{-1} of NPK 17-17-17 + 49 kg ha^{-1} of urea (46 %)]. However, for farmers who would opt to use open-pollinated variety due to their affordability or any other reason it is recommended to use 'Sugar Baby' and apply 100 % of the recommended fertilizer dose 90:60:60. Further studies are recommended to validate the findings of this study in other areas.

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