MORE FRUITS WERE SET BY APPLICATION OF IODINE WITH POTASSIUM NITRATE AS SOIL APPLICATION IN 'MALUMA HASS' AVOCADO IN TZANEEN

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ABSTRACT

A 2-year trial on 'Maluma Hass' avocado supported the hypothesis of a benefit of iodine (I) for fruit yield. Iodine is now considered a beneficial micronutrient in plants. It is involved in photosynthesis, the production of anti-oxidant compounds, and in root growth and function. It can be covalently bound by the plant in at least 82 plant proteins. These proteins are important for photosynthesis and the response to stress signals.

Foliar and soil applications of KNO_3 with or without I were compared to the growers' practice of K_2SO_4 and limestone ammonium nitrate (LAN) in two factorial Randomised Complete Block trials. In the first year, foliar application of KNO_3 improved leaf concentration of N and I. Soil applied KNO_3+I resulted in a higher number of fruits set after bloom, a pronounced effect of iodine on the harvested number of fruits per tree and 63% more kg fruit per tree, compared to soil applied K_2SO_4. Foliar applied KNO_3+I resulted in a similar yield increase compared to no foliar fertilizer application.

In the second year the effect of I and KNO_3 was studied in more detail. The effect observed from foliar applied KNO_3+I in the previous year was not confirmed. The results confirmed the beneficial effect of soil applied KNO_3+I on fruit set. Ninety days after bloom, soil applied KNO_3+I resulted in 32% more fruits set compared to the control K_2SO_4 application. This was higher than the benefit observed from soil applied KNO_3 without iodine, where 14% more fruits set.

UITTREKSEL

'n Tweejaarproef op 'Maluma Hass' avokado ondersteun die hipotese van 'n voordeel van jodium (I) vir vrugopbrengs. Jodium word nou as 'n voordelige mikrovoedingstof in plante beskou. Dit is betrokke by fotosintese, die produksie van anti-oksidantverbindings en by wortelgroei en -funksie. Dit kan kovalent deur die plant in ten minste 82 plantproteïene gebind word. Hierdie proteïene is belangrik vir fotosintese en die reaksie op stremmingseine.

Blaar- en grondtoedienings van KNO_3 met of sonder I is vergelyk met die landboupraktyke van K_2SO_4 en kalksteenammoniumnitraat in twee faktoriële ewigkansige blokontwerp-proewe. In die eerste jaar het blaartoediening van KNO_3 die blaarkonsentrasie van N en I verbeter. Grondtoegediende KNO_3+I het gelei tot 'n hoër aantal vrugte wat na blom geset het, 'n uitgesproke effek van jodium op die geoeste aantal vrugte per boom en 63% meer kg per vrugteboom, in vergelyking met grondtoegediende K_2SO_4. Blaartoegediende KNO_3+I het 'n soortgelyke opbrengsverhoging tot gevolg gehad in vergelyking met geen blaarbemestingstoediening nie.

In die tweede jaar is die effek van I en KNO_3 in meer besonderhede bestudeer. Die effek waargeneem van blaartoegediende KNO_3+I in die vorige jaar is nie bevestig nie. Die resultate het wel die voordelige effek van grondtoegediende KNO_3+I op vrugset bevestig. Negentig dae na blom het grondtoegediende KNO_3+I gelei tot 32% meer vrugset in vergelyking met die kontrole K_2SO_4 toediening. Dit het 'n hoër voordeel van 14% meer vrugset gelewer as die voordeel waargeneem uit grondtoegediende KNO_3 sonder jodium.

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INTRODUCTION

Fruit set and early fruit drop is a critical period in the crop cycle from the perspective of the producer. Factors that influence fruit retention have a direct influence on the final yield of the crop. Potassium (K) is crucial for fruit retention, as it improves water regulation, photosynthesis efficiency, acts as a cofactor in protein synthesis, and supports the transport of nutrients and sugars essential for fruit development (Rengel *et al.*, 2022; Vreugdenhil, 1985). Of all macro nutrients, K is the most abundant nutrient both in the tree wood and avocado fruit (Snijder and Stassen, 2000). Because of the high K content in fruit, much of the K reserve in the soil is removed with harvest (Rebolledo-Roa and Burbano-Diaz, 2023). To prevent a deficiency in the crop of this important nutrient, K can be applied as a soil fertilizer, by fertigation, or as a foliar spray (Fernández *et al.*, 2013).

Iodine (I) is recently added to the list of plant nutrients, following the new definition of plant nutrients (Brown *et al.*, 2022; Kirkby, 2023). The proposed role of iodine in plants is the ability of plants to covalently bind iodine on a large diversity of proteins that have active roles in various aspects of the plant's metabolism. Kiferle *et al.* (2021) have elegantly demonstrated in *Arabidopsis thaliana*, that the development of plants, fruits, and the speed of flowering is greater in presence of a micromolar dose of iodine in the nutrient solution, compared to plants with a negligible amount of iodine in the water. Moreover, the stimulating effect of a small amount of iodine on nitrogen metabolism, carbon metabolism, oxidative stress reducing pathways, and production of antioxidants has been recorded for at least 30 crops, reviewed by Medrano-Macías *et al.* (2016). Since the nomination of iodine as a plant nutrient, more recent studies on its effect in plant metabolism confirm that it has a beneficial role for crop development and yield, especially in plants suffering from abiotic stress (e.g. Kiferle *et al.*, 2022; Andrade *et al.*, 2024). Applications of iodine as a micronutrient in fertigation by producers, using KNO_3 as a carrier, have demonstrated its value for vegetable production (Hora and Holwerda, 2021, 2023).

In the terrestrial environment, and especially in agricultural systems, the plant available amount of iodine is generally low. Despite the presence of iodine in the soil, in general, less than 10% of that iodine is available in the soil solution (Shinonanga *et al.*, 2001; Duborská *et al.*, 2020). In a study of iodine content of irrigation water from 40 farm locations in Southern Africa, the average was 0.46 ± 0.41 μmol L^{-1}, and 28 of 40 samples (70%) contained much less than the average value (Hora *et al.*, in press).

To date, to the best of our knowledge, there are no scientific publications describing the application of iodine as a micronutrient in avocado. The trial on 'Maluma Hass' avocado, described in this paper, examined the benefit of iodine for fruit set and fruit retention. The hypothesis of this mode of action of iodine stems from the benefits of iodine on flowering, fruit set, and fruit growth observed in *Arabidopsis thaliana* and tomato (Kiferle *et al.*, 2021, 2022). Iodine was applied both in a foliar fertilizer application and in a soil fertilizer application. For ease of application for growers, iodine was combined in soil- and foliar spray-applied KNO_3, intended to provide the trees with sufficient K to support fruit retention. KNO_3 sprays made during flowering are considered to improve fruit retention and size by increasing the efficiency of phloem translocation of assimilates (Singh and McNeil, 1992). To separate the effect of KNO_3 from the effect of iodine, both KNO_3 with or without iodine was compared to K_2SO_4 as a soil applied source of K.

MATERIALS AND METHODS

Trial field and design

The orchards where the trial were established were located in the vicinity of the Tzaneen Dam, Limpopo, South Africa. In the first year's trial orchard, trees of cultivar Maluma Hass were half grown bearing trees planted at a density of 416 trees ha^{-1}. For the second year an orchard with fully grown trees was selected (Figs. 1 and 2). Both orchards were under the same grower's management. Soil and irrigation water analyses of minerals and other soil and water quality parameters were performed for the first orchard before the trial in August 2022, according

Figure 1: The orchard in Tzaneen where the trial was established in for the first trial year.

Figure 2: The orchard in Tzaneen where the trial was established in for the second trial year.

to the AgrilASA quality control scheme (Barnard *et al.*, 2005) and the prescribed standard methods of analyses. The total of all iodine species in the irrigation water was measured with ICP-MS after alkaline extraction (Table 1).

The trial was a factorial, randomised block design, with 10 individual tree replicates per treatment, with 8 treatments in 2022, and 6 treatments in 2023. The two factors were the application method, either on the soil or by foliar spray. Prior to flowering in September, trees of similar appearance were labelled and divided over the treatment groups. For each year, new trees were selected. In all treatments, the farm practice recommendation of total application of N and K in the prescribed crop stage was followed. No calcium was applied in these orchards, but zinc and boron were applied with foliar sprays over all trees following the farm practice. For comparison of soil applied KNO_3 with potassium sulphate, the total K and N was kept the same (Table 2a).

The total amount of fertilizers was split equally over two application times, and timing of both soil and foliar treatments was the same. The first application was done at the start of flowering, end of August, and the second application one month later. On the application dates, the soil fertilizer treatments were applied on the micro sprinkler wetting area. In the first year, all KNO_3 that was soil applied contained 0.1% iodine (hereafter KNO_3+I), and foliar applications of KNO_3 with or without iodine were compared. In the second year the comparison was made between KNO_3 with or without iodine in the soil application, and all foliar applications were made with KNO_3+I (Table 2b). For foliar spray applications, solutions were made up in 16 L knap sack spray-

Table 1a: Tzaneen orchard, soil analysis prior to the trial in 2022

Parameter	Method	Unit	
pH	KCl		5.1
NH_4-N	KCl	mg/kg	1.12
NO_3-N	KCl	mg/kg	6.41
P	Bray 1	mg/kg	4
K	Am Ac	mg/kg	117
Ca	Am Ac	mg/kg	723
Mg	Am Ac	mg/kg	152
Na	Am Ac	mg/kg	18
K	Calculated	%	5.7
Ca	Calculated	%	69.0
Mg	Calculated	%	23.8
Na	Calculated	%	1.5
K	Calculated	meq = cmol(c)/kg	0.30
Ca	Calculated	meq = cmol(c)/kg	3.62
Mg	Calculated	meq = cmol(c)/kg	1.25
Na	Calculated	meq = cmol(c)/kg	0.08
Ca:Mg	Calculated		2.9
(Ca+Mg)/K	Calculated		16.2
Mg:K	Calculated		4.2
Cu	0.1M HCl	mg/kg	5.95
Zn	0.1M HCl	mg/kg	1.26
Mn	0.1M HCl	mg/kg	18.60
Fe	0.1M HCl	mg/kg	11.88
B	H_2O	mg/kg	0.33
S	Am Ac	mg/kg	50.4
Density		g/cm³	0.976
Carbon	WalkeyBlack	%	1.04
OM		%	1.79

Table 1b: Tzaneen orchard, irrigation water analysis

Parameter	concentration meq l^{-1}	
Alkalinity	33	mg l-1 $CaCO_3$
EC	15	mS/m @25 °C
pH	8.3	@25 °C
Total dissolved solids	98	mg l^{-1}
SAR	0.55	index
Bicarbonate as $CaCO_3$	0.66	meq l^{-1}
Cl^-	0.15	meq l^{-1}
SO_4^{2-}	0.08	meq l^{-1}
NO_3^-	0.43	meq l^{-1}
H_2PO_{4-}	0.0	meq l^{-1}
Ca^{2+}	0.4	meq l^{-1}
Mg^{2+}	0.4	meq l^{-1}
K^+	0.0	meq l^{-1}
Na^+	0.4	meq l^{-1}
NH_4^+	0.03	meq l^{-1}
Cu^{2+}	0.009	mg l^{-1}
Zn^{2+}	0.073	mg l^{-1}
Mn^{2+}	<LOQ	mg l^{-1}
Fe^{2+}	0.039	mg l^{-1}
B^{3+}	0.011	mg l^{-1}
Total I	0.16	µmol l^{-1}

Table 2a: Soil applied fertilizers; total amount split over 2 applications

Trial year	2022-23		2023-24	
Treatment	K_2SO_4	KNO_3 w/wo I	K_2SO_4	KNO_3 w/wo I
Fertilizer source	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
Potassium sulphate	324	0	208	0
LAN	208	0	291	67
Magnesium sulphate	175	175	175	175
KNO_3 w/wo 0.1% I	0	359	0	230
Ammonium sulphate	0	55	0	156
Total N	81.5	81.5	58.2	58.2
Total K	87.4	87.4	136.4	136.4

ers, and a full cover spray was applied to run off up-down-and-around. The foliar applied treatments added a modest amount of K, N-NO_3 and I, by application of two foliar sprays at 2% or 3% w/v with approximately 1330 L/ha.

In the first year, leaves were sampled end of October (1 month after the second application) from each tree for nutrient analyses (% N, P, K, Ca, Mg, and ppm Mn, Fe, Cu, Zn, B in dry matter). Iodine content was analysed in the leaf dry matter from a sample pooled per treatment over the replicate trees, by a commercial laboratory following their standard method for analyses of iodine in silage and hay, based on ICP-MS, conforming to NEN 17294-2.

On three occasions, the number of fruit per tree was counted. The clothes peg method (place peg on each fruit, take off pegs and count them) was used to count the number of fruit on the tree, 2 and 3 months after bloom, end of October and end of November. To assess early fruit drop, the number of fruit on the tree at the later dates was expressed as a percentage of the fruit at the first count. In 2022, all fruit were harvested in March, and the number of harvested fruit per tree was counted. The fruit were individually weighed to derive the average fruit weight. The total weight of all fruit per tree was recorded to estimate yield. In 2023, based on the observations of the previous year's trial, only fruit set was evaluated since this was the stage when addition of iodine in the fertilizers seemed to have the greatest effect. The fruit were counted on five representable, uniform, trusses per tree, labelled at time of the first fertilizer application, and the total of these 5 trusses per tree was used for data analyses. Unfortunately, the total tree yield at harvest time could not be evaluated in the second year.

The data was analysed using ARM (Agricultural Research Manager, revision 2024.1). Interactions between the soil vs. foliar application were analysed using factorial ANOVA, and when no interactions were observed, the grouped factor means separation was based on LSD α=0.1. A log-transformation was applied before analyses when the data were not normally distributed.

RESULTS AND DISCUSSION

Leaf nutrients

Leaf nutrients were measured in the first year, on leaves sampled one month after the second application. No significant interaction between the soil applied or the foliar applied treatments were identified, therefore the factor means are presented in Table 3. Most nutrients were not affected by the treatments. Except for a slightly low overall Ca concentration, no limiting nutrient for yield in the crop was indicated for any treatment.

Differences were found in leaf dry matter concentration of N, P, Mn, and Zn only between the foliar applied treatments. The highest N was found after application of 2% KNO_3+I and 2% KNO_3. All foliar applied KNO_3 reduced P levels, but these still remained higher than recommended in all treatments. Mn was lowest in the 2% KNO_3+I treatment and Zn was lowest in the 2% KNO_3 treatment, but both micronutrient concentrations were well within the sufficiency range.

There was an interaction between the factors soil

Table 2b: Trial treatment factorial combinations and total iodine applied in each treatment

Application placement and K-source			Total Iodine applied I (g/ha)
	Soil applied	Foliar applied	
No.	2022-2023		
1	S: K_2SO_4	C: Control	0
2	S: K_2SO_4	N2%: KNO_3 2% w/v	0
3	S: K_2SO_4	N3%: KNO_3 3% w/v	0
4	S: K_2SO_4	NI2%: KNO_3+0.1%I 2% w/v	53
5	NI: KNO_3+0.1%I	C: Control	359
6	NI: KNO_3+0.1%I	N2%: KNO_3 2% w/v	359
7	NI: KNO_3+0.1%I	N3%: KNO_3 3% w/v	359
8	NI: KNO_3+0.1%I	NI2%: KNO_3+0.1%I 2% w/v	412
No.	2023-2024		
1	S: K_2SO_4	C: Control	0
2	S: K_2SO_4	NI2%: KNO_3+0.1%I 2% w/v	53
3	N: KNO_3	C: Control	0
4	N: KNO_3	NI2%: KNO_3+0.1%I 2% w/v	53
5	NI: KNO_3+0.1%I	C: Control	230
6	NI: KNO_3+0.1%I	NI2%: KNO_3+0.1%I 2% w/v	283

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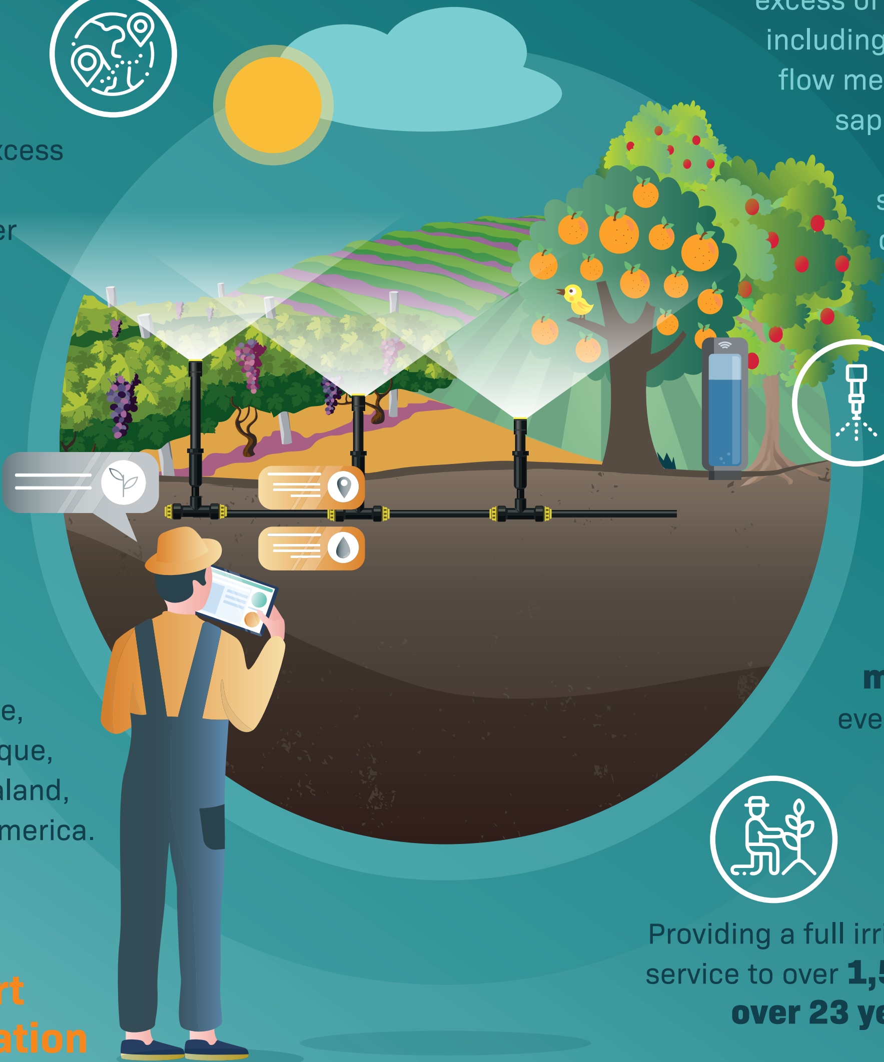

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Table 3: Nutrient concentration in dry matter of avocado leaves

Nutrient	N		P		K		Ca		Mg		Mn		Fe		Cu		Zn		B	
Treatment factors	**%**		**%**		**%**		**%**		**%**		**ppm**		**ppm**		**ppm**		**ppm**		**ppm**	
A soil applied																				
S	2.68	a	0.40	a	1.19	a	1.13	a	0.48	a	210	a	141	a	428	a	46	a	65	a
NI	2.77	a	0.40	a	1.22	a	1.12	a	0.49	a	220	a	133	a	420	a	48	a	59	a
LSD P=.10	0.13		0.07		0.05		0.04		0.02		33		11		34		8		10	
St. Dev.	0.31		0.17		0.12		0.09		0.04		81		26		84		20		23	
B foliar applied																				
C	2.63	b	0.47	a	1.21	a	1.11	a	0.49	a	238	a	138	a	417	a	57	a	69	a
N2%	2.74	a	0.36	b	1.20	a	1.11	a	0.50	a	220	ab	144	a	424	a	38	c	66	a
N3%	2.72	ab	0.39	b	1.19	a	1.14	a	0.48	a	207	ab	129	a	415	a	46	bc	58	a
NI2%	2.80	a	0.39	b	1.22	a	1.14	a	0.48	a	195	b	136	a	439	a	49	ab	57	a
LSD P=.10	0.11		0.08		0.05		0.05		0.03		38		21		46		10		15	
St. Dev.	0.20		0.14		0.09		0.09		0.06		70		38		86		18		27	
*Sufficiency range**	2.2-2.4		0.1-0.2		0.75-1.15		1.2-2		0.5-0.6		75-250		75-150		5-15		25-100		40-50	

*(SAAGA, 2023)

and foliar spray application for leaf concentration of iodine. These numbers could not be analysed statistically since we had one combined sample per treatment. The irrigation water contained only 0.16 micromol L^{-1} of iodine therefore it was expected that the iodine concentration in leaves of the control trees was lower than that in the trees receiving KNO_3+I. One month after the second application, leaf I concentration was raised by the soil application of KNO_3+I in all treatments that had received foliar sprayed KNO_3 with or without iodine (1.0-1.6 mg I kg DM^{-1}), compared to the K_2SO_4 soil applied treatments (0.6-0.7 mg I kg DM^{-1}). When KNO_3 was foliarly applied, there was no increase in leaf iodine between the applications of 2% KNO_3 and 2% KNO_3+I.

Plants are known to be able to take up iodine from a foliar application, and to be able to translocate iodine via the phloem to new leaf growth and generative organs (Cakmak *et al.*, 2017; Landini *et al.*, 2011). Nevertheless, the relatively small amount of iodine applied with the foliar spray in the avocado trial may not have been sufficient to make a significant difference in the concentration of iodine in the leaf dry matter one month after the last application, especially if this iodine had already been translocated to the flower bunches and the developing fruit. Moreover, it is uncertain if leaf absorbed iodine will be translocated to the roots, the plant's preferential organ for iodine accumulation (Gonzali *et al.*, 2017).

Leaf iodine was not higher in soil applied KNO_3+I than in the K_2SO_4 treatment, (respectively 0.3 mg I kg DM^{-1} and 0.8 mg I kg DM^{-1}). This is a puzzling finding which needs more investigation. We can only speculate, based on evidence that iodine is involved in nitrogen metabolism (Medrano-Macías *et al.*, 2016) and seems to be stored by plants in root tissue to a higher concentration than in leaves (Dobosy *et al.*, 2024). Possibly the amount of N-NO_3 taken up in leaves from the foliar applications, shown also by a higher total N content of these leaves, had somehow stimulated translocation of I from a reserve of I in roots after the soil applied KNO_3+I, to the leaves in trees that had received the foliar treatments. This effect did not occur in the trees in the K_2SO_4 treatment that had not received a soil application of iodine and may not have had a sufficient reserve of I in the roots.

Fruit set

Table 4 shows the effect of the treatments on small fruit set, 3 and 4 months after bloom and the first fertilizer application. No significant interactions between the soil applied or the foliar applied treatments were identified, therefore the factorial treatment means are presented. In both years, the number of fruit present on the trees on both assessment dates, was clearly and statistically significantly greater in the trees where soil application of KNO_3+I was made.

Spray application of KNO_3+I also resulted in a greater number of fruit in the first trial year. The 2% foliar applied treatments resulted in a higher fruit drop between the two counting dates, compared to the unsprayed control, possibly related to the absolute higher number of fruit on the trees fertilized with KNO_3+I. The 3% KNO_3 spray did not affect these parameters compared to the unsprayed control. In the second year, no additional effect of spray applied KNO_3+I was observed. In neither year was the percentage of fruit dropped between the assessment dates affected by the soil applied treatments. It seems that the effect of the treatments on fruit set was already established before the first fruit count.

In the first year, overall fruit set and retention in this orchard were markedly reduced, possibly due to abnormal environmental conditions during flowering. Iodine is known for a beneficial role for flowering, the response of plants to stress, and production of antioxidants (Medrano Macías, 2016; Kiferle *et al.*, 2021; Kiferle *et al.*, 2022). Possibly the relatively small amount of iodine applied with the foliar sprays at bloom contributed more to this protective effect under the stressful conditions in 2022, compared to the second year.

Yield

An effect of KNO_3+I on yield was visible in both the soil and the foliar applied treatments (Table 5). The yield in the first year was remarkably (+62%) and statistically significantly higher in the treatments where KNO_3+I was applied, compared to the soil application with K_2SO_4 as K-source. This was mainly due to the higher number of fruit (+65%) on the trees, already present before the first count in the small fruit stage. Similarly higher fruit set and corresponding yield increase were seen in the treatment where KNO_3+I was applied as a foliar spray compared to the unsprayed control. The same concentration of KNO_3 applied foliarly had also resulted in extra yield (19%), but this effect was not statistically significant. The treatments did not significantly affect the percentage drop of fruit before harvest.

The average fruit weight was lower in the soil applied KNO_3+I treatment which is to be expected from the higher number of fruit on the tree, based on the trade-off between fruit load and individual fruit weight. The individual fruit weights were well within the commercial size classes 16-18 for 'Maluma Hass' avocado, which is the preferred size for export to Europe (Staatskoerant, 2013; CBI, 2024).

Table 4: Number of fruit per tree or labelled trusses on different assessment dates and percentage fruit drop relative to the first count

Year	**2022-2023**					
Date	28-Oct-22		28-Nov-22		28-Nov-22	
Days after first application	59		90		90	
Assessment	No. fruit tree^{-1}		No. fruit tree^{-1}		% fruit drop	
Treatment: Factor A soil applied						
S	16.7	b	14.9	b	8.0	a
NI	26.7	a	24.5	a	6.6	a
LSD P=.10	*6.3-7.3*		*5.6-6.6*		3.2-3.6	
St. Dev.	*0.32t**		*0.32t**		1.49t*	
Treatment: Factor B foliar applied						
C	16.8	b	15.6	b	5	b
N2%	21.4	ab	18.9	ab	8.8	a
N3%	18.6	b	16.9	b	7.1	ab
NI2%	29.9	a	26.8	a	8.5	a
LSD P=.10	*7.8-9.4*		*7.4-8.6*		*3.1-3.2*	
St. Dev.	*0.29t*		*0.30t**		*1.8t**	
Year	**2023-2024**					
Date	27-Oct-23		30-Nov-23		30-Nov-23	
Days after first application	58		92		92	
Assessment	No. fruit 5 trusses^{-1}		No. fruit 5 trusses^{-1}		% fruit drop	
Treatment: Factor A soil applied						
S	7.2	b	5.6	b	19.5	a
N	8.2	a	6.4	b	19.5	a
NI	8.4	a	7.4	a	11.6	a
LSD P=.10	*0.99*		*0.95*		*9*	
St. Dev.	*1.87*		*1.79*		*17.03*	
Treatment: Factor B foliar applied						
C	7.6	a	6.5	a	15.6	a
NI2%	7.8	a	6.4	a	18.1	a
LSD P=.10	*0.81*		*0.78*		*7.4*	
St. Dev.	*1.87*		*1.79*		*17.03*	

*t dataset was log transformed before analyses to correct the distribution to normality for ANOVA, the standard deviation was not de-transformed.

CONCLUSIONS

The aim of the study was to assess the effect of potassium nitrate (KNO_3) foliar sprays or iodine (I) enriched KNO_3 foliar sprays and/or soil application of K_2SO_4, KNO_3 or KNO_3+I on fruit set and on post flowering fruit drop and yield of 'Maluma Hass' avocado.

To the best of our knowledge, this is the first study to be published on the effect of iodine as a micronutrient in fertilizers, on yield of avocado trees. Therefore, the observations of this study can be considered as a starting point for more in-depth research into the application of iodine for the benefit of yield in this crop.

The results show that 230-359 g ha^{-1} of soil applied iodine, combined with KNO_3, had a beneficial effect on the fruit set in 'Maluma Hass' avocado, compared to application of K_2SO_4 in each of the two consecutive trial years. Soil applied KNO_3 without iodine also increased fruit set compared to application of K_2SO_4, but this resulted in a less distinct increase (+14%), compared to KNO_3+I (+32%). Foliar applied KNO_3+I (53 g ha^{-1}) also resulted in more fruits set in the first year but this was not confirmed in the second year.

The extra fruit set and extra total yield in the first year was around +60% from soil or foliar applied KNO_3+I compared to K_2SO_4. With the observation that in that year fruit set was severely negatively affected by climatic conditions during bloom, the foliar iodine application may have been timed exactly right to boost the resilience of the plant to this transient abiotic stress.

These preliminary findings suggest that iodine may be lacking in avocado trees in South Africa, resulting in a limitation in crop-production under stressful conditions. Following this line of thought, further studies require a similar approach as has been taken to study other micronutrients in the past. More research into the potential of iodine-containing fertilizers to improve production of avocado is needed.

Avenues for future research are the investigation of the uptake and distribution of iodine in different organs of avocado crops, the critical crop stages where a deficiency of iodine should be corrected with foliar spray and the potential of a balanced nutrition programme including iodine among all known plant nutrients, to prevent yield loss due to climatic stresses such as heat, drought or saline soil or water conditions. Responsible use of plant nutrition offers a great opportunity to improve crop resilience and yield security in an unpredictable climate, and iodine may be one of the nutrients that is limiting to achieve the crops yield potential.

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Table 5: Number of fruit and percentage fruit drop at harvest time, since the first fruit count, and yield of 'Maluma Hass' avocado in number of fruit tree^{-1} and g fruit^{-1}. MT ha^{-1} yield is calculated from the per tree yield by multiplying with the orchard's tree density of 416 trees ha^{-1}

Year	**2022-2023**									
Date	24-Mar-23									
Assessment	No. fruit tree^{-1}		% fruit drop		g fruit^{-1}		kg tree^{-1}		MT ha^{-1}	
Treatment: Soil applied										
S	14.7	b	9.2	a	231.3	a	3.5	b	1.5	b
NI	24.3	a	7.5	a	225.9	b	5.7	a	2.5	a
LSD P=.10	*5.5-6.5*		*3.1-3.3*		*3.3*		*1.3-1.5*		*0.6-0.7*	
St. Dev.	*0.32t**		*1.31t**		*8.0*		*0.28t**		*0.23t**	
Treatment: Foliar applied										
C	15.3	b	6.4	b	229.4	a	3.7	b	1.6	b
N2%	18.7	ab	9.7	ab	227.3	a	4.4	ab	1.9	ab
N3%	16.9	b	7.4	ab	229.5	a	4.0	b	1.8	b
NI2%	26.4	a	10.1	a	228.2	a	6.2	a	2.7	a
LSD P=.10	*7.1-8.3*		*3.5-3.6*		*4.5*		*1.7-1.9*		*0.7-0.8*	
St. Dev.	*0.29t**		*1.12t**		*8.3*		*0.25t**		*0.20t**	

*t dataset was log transformed before analyses to correct the distribution to normality for ANOVA, the standard deviation was not de-transformed.

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