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Nitrogen Effect on Fruit Quality and Yield of Muskmelon and Sweet Pepper Cultivars

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Abstract: Yield and fruit quality are two of the most important parameters for the profitability of vegetable crops. In commercial vegetable production, nitrogen (N) is commonly applied in excess, which is associated with nitrate (NO_3^-) leaching loss. In addition, excess N application may affect yield and fruit quality. The aim of this study was to evaluate the effect of N applications of very deficient N (N1, 2 mmol L^{-1}), deficient N (N2, 8 mmol L^{-1}), and conventional N (N3, 14 mmol L^{-1}), according to local fertigation practices, in soil-grown muskmelon and sweet pepper crops in Almeria, South-Eastern Spain. The evaluation was conducted in three cultivars of each species. The yield and the fruit quality parameters of firmness, colour, total soluble solids (TSS) and morphometric variables were evaluated in two years for each species. For most parameters in both species, the effects of N, when significant, occurred regardless of cultivar. In muskmelon and sweet pepper, application of 8.2 mmol N L^{-1} (i.e., N2) was sufficient to achieve a maximum yield of 6.7 and 7.4 kg m^{-2}, respectively. In muskmelon, very deficient N application led to an increase of 58% in the percentage of fruit discarded, mostly due to malformed and undersized fruits. Fruit firmness and red–green axis coordinate (a*) were not consistently affected by N in any of the crops. However, the fruit lightness (L*) increased with N addition in both species, likely because of increased chlorophyll pigments. With N addition, fruit TSS slightly decreased in muskmelon and slightly increased in sweet pepper. However, fruit TSS of both species were within reference values for commercialisation in the three N treatments. There were differences in yield between cultivars in muskmelon but not in sweet pepper, likely due to differences in fruit number in muskmelon. There were differences between cultivars in TSS and colour a* coordinate in both muskmelon and sweet pepper. Cultivars with higher TSS and a* coordinate will likely be more desirable for consumers because of the sweeter taste and more intense orange colour in muskmelon and reddish colour in sweet pepper. Overall, our manuscript showed that N application can be reduced, relative to the conventional N application, without reducing yield or fruit quality in muskmelon, yet additional studies should be conducted in sweet pepper to complement the results of the 2020 crop.

Keywords: *Capsicum annuum*; colourimeter; *Cucumis melo*; fertilisation; firmness; nitrogen; total soluble solids

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1. Introduction

There is a high concentration of plastic greenhouses in South-Eastern (SE) Spain that are used for vegetable production. More than 32,500 hectares are located in the province of Almeria [1]. A variety of vegetable crops are grown, mostly for export to Northern European countries [2]. In Almeria, two of the most important crops are sweet pepper and muskmelon, with annual cropped areas of 12,310 and 3205 ha in 2021, respectively [1].

The annual value of sweet pepper and muskmelon production are approximately EUR 700,000,000 and EUR 53,430,000, respectively [1]. Sweet pepper is mostly grown with a summer to winter cropping cycle and melon with a spring to summer cycle. Often, these crops are grown in sequence [3].

The high concentration of greenhouses in SE Spain is associated with intensive use of resources, such as water and fertilisers. In general, in commercial greenhouse vegetable production, management of irrigation and fertilisers is based on the experience of producers and technical advisors [4]; N is commonly applied in excess [4–8] to ensure that N does not limit yield [9,10]. Insufficient N supply may result in low yield and small fruits, whereas excessive N can delay fruit ripening [11,12]. In addition, applications of excessive N may be an unnecessary cost that is commonly associated with negative environmental impacts such as nitrate (NO_3^-) leaching losses [13]. In addition, there are reports that N supply affects fruit quality parameters such as fruit total soluble solids (TSS) [14–16] and fruit firmness [17].

There is appreciable research reporting the effects of cultivars on yield and various parameters of fruit quality in vegetable crops [10,18,19]. However, much of the research has focussed on tomato [10,18,20,21]. In muskmelon, significant differences were found between cultivars in yield, fruit morphometric parameters [22], TSS, titratable acidity and beta carotenes [23,24]. In the case of sweet pepper, differences between cultivars were also found in beta carotene, ascorbic acid, total flavonoids, and soluble phenols [25].

The high concentration of greenhouses in SE Spain and the overuse of N fertiliser, in this system, have caused substantial aquifer contamination with NO_3^-. In accordance with the European Union legislation [26], most of the greenhouse cropping areas of SE Spain have been declared to be nitrate vulnerable zones [27] which requires the implementation of improved crop management practices to reduce NO_3^- contamination of water bodies [4,6,13]. An additional and important consideration is that consumers are increasingly demanding high product quality and environmentally friendly production of fruits and vegetables [6,28].

Given the importance of muskmelon and sweet pepper, and the N management issues in the greenhouse system of SE Spain, information is required on the effects of reduced N on the yield and fruit quality of these two species. The objective of this work was to evaluate the response of yield and parameters of fruit quality to conventional and deficient N fertilisation in different cultivars of muskmelon and sweet pepper. We hypothesised that conventional N application, based on local fertigation practices, is excessive and yield and fruit quality can be maintained with reduced N application. To rule out the influence of cultivars on N effects, the evaluation was conducted with three different cultivars of each species from different seed companies.

2. Materials and Methods

2.1. Crops and Experimental Site

Two crops of muskmelon (*Cucumis melo* L.) and two crops of sweet pepper (*Capsicum annuum* L.) were grown in soil in a greenhouse [29], at the Experimental Farm of the University of Almeria (UAL), in Almeria (SE Spain, 36°51′ N latitude, 2°16′ W longitude; 92 m above sea level). The two muskmelon crops and the first sweet pepper crop were grown in the same greenhouse (unit U13 of the UAL Farm), whereas the second sweet pepper crop was grown in a different greenhouse (unit U14 of the UAL Farm) because of maintenance work in the former U13 unit. Soil mineral N (0–0.4 m) at planting was much higher in U14 greenhouse than in U13 because of insufficient leaching of residual N in U14 (Table 1). In both greenhouses, the cropped area was approximately 1300 m^2 and the soil was artificially stratified at greenhouse construction; the stratified soil consisted of a layer of silty loam soil (0.3 m thickness) placed over the original sandy loam soil and a mulch layer that consisted of either coarse sand (unit U13) or a black polyethylene film (unit U14).

Table 1. Mineral N (NO_3^-–N + NH_4^+–N) in soil (0–0.4 m depth) at the beginning of each crop, N concentration in the nutrient solution applied and mineral N amount applied in fertigation in the four crops.

Crop	Year of Transplant	N Treatment	Mineral N at Planting (kg N ha^{-1})	N Concentration in Nutrient Solution (mmol L^{-1})	N Amount Applied (kg N ha^{-1})
Muskmelon	2020	Very deficient (N1)	63	2.7	61
		Deficient (N2)	50	8.3	302
		Conventional (N3)	38	14.0	582
	2021	Very deficient (N1)	13	2.7	57
		Deficient (N2)	77	8.0	228
		Conventional (N3)	79	14.6	515
Sweet pepper	2020	Very deficient (N1)	31	2.2	66
		Deficient (N2)	18	8.4	428
		Conventional (N3)	42	14.2	704
	2021	Very deficient (N1)	340	1.9	70
		Deficient (N2)	346	8.2	337
		Conventional (N3)	290	14.2	615

Drip irrigation and fertigation were used with paired drip lines arranged with a separation of 0.8 m. There was a 1.2 m separation between adjacent paired lines. Drippers with a flow rate of 3 L h^{-1} were positioned every 0.5 m in each drip line, close to a plant. Planting density was two plants per m^{-2}.

All cultural practices were conducted according to local crop management. Climatic conditions inside the greenhouses throughout the crops were measured and recorded in a data logger. Fertigation commenced two and eight days after transplanting (DAT), for the muskmelon and sweet pepper crops, respectively. Complete nutrient solutions were applied for macro and micronutrients, except for N application where three treatments with different N concentrations were applied in the nutrient solution.

2.2. Experimental Design

The first muskmelon crop was transplanted on 27 February and harvested on 11 June 2020 (105 days). The second muskmelon crop was transplanted on 26 February and harvested on 8 June 2021 (102 days). The cultivars selected were among the most frequently used by local farmers and came from different seed companies. Three cantaloupe-type muskmelon cultivars were evaluated: Tezac (Seminis, Inc., Bayer AG, Leverkusen, Germany), Magiar (Nunhems, BASF SE, Ludwigshafen, Germany) and Jacobo (Semillas Fitó, Barcelona, Spain). The cultivar Tezac was replaced by the cultivar Bosito (Seminis, Inc.,) in the second muskmelon crop because of the discontinuation of the former.

The first sweet pepper crop was transplanted on 22 July 2020 and harvested on 28 January 2021 (190 days). The second sweet pepper crop was transplanted on 22 July 2021 and harvested on 9 January 2022 (171 days). The second sweet pepper crop was shorter than the first crop because of a high incidence of powdery mildew (*Leveillula taurica*) towards the end of the crop. The cultivars selected were among the most frequently used by local farmers and came from different seed companies. The cultivars used were: Melchor (Zeraim Iberica, Syngenta Crop Protection AG, Basel, Switzerland), Machado (Hazera Seeds Ltd., Limagrain Group, Saint Beauzire, France) and CLX PLRJ 731 (HM.CLAUSE SAS, La Motte, Portes-lès-Valence, France).

In both the U13 and U14 units, there were 12 experimental plots of approximate 12 m × 6 m. In each experimental plot, each of the three cultivars was planted in two paired lines of plants (i.e., four lines in total of 13 plants each) for a total of 52 plants per cultivar (i.e., 156 plants in total per plot). The position of cultivars in each plot was randomised.

Three treatments with different N concentrations were applied in the nutrient solution by fertigation. There were four experimental plots of 12 m × 6 m of each N treatment, with a total of 156 plants per treatment. Intended N concentrations for both species were 2, 8 and 14 mmol N L^{-1}, for very deficient N (N1), deficient N (N2), and conventional N application (N3), respectively, according to local practices [30]. The treatments are described in terms of applied N concentration (mmol L^{-1}) and the amount of mineral N applied (NO_3^-–N + NH_4^+–N; kg N ha^{-1}) in Table 1. For all treatments, N was applied mostly as NO_3^- (95% in muskmelon and 94% in sweet pepper), the rest as ammonium (NH_4^+). Concentration of other macro and micronutrients were applied at the same non-limiting concentration in all three treatments: HPO_4^-, 2 mmol L^{-1}; K^+, 4 mmol L^{-1}; Ca^{+2}, 4 mmol L^{-1}; Mg^{+2}, 1.5 mmol L^{-1}; SO_4^{-2}, 2.35 mmol L^{-1}. Irrigation volume was adjusted to maintain the soil matric potential in the range −15 to −25 kPa at 0.1 m depth from the surface of the imported loam soil. One tensiometer (Irrometer, Co., Riverside, CA, USA) was installed in the same cultivar in each replicate plot of each crop. All cultivars in each N treatment were irrigated equally.

2.3. Fruit Yield Evaluation

Total yield was calculated by summing the fresh weight of mature fruit of muskmelon, and of red fruit of sweet pepper that were collected throughout the crop, from eight marked plants of each cultivar, in each plot. In the 2020 muskmelon crop, there were two fruit harvests at 96 and 104 DAT; in the 2021 muskmelon crop, there was one harvest at 101 DAT. In the 2020 sweet pepper crop, there were six harvests between 98 and 187 DAT. In the 2021 sweet pepper crop, there were four harvests between 90 and 160 DAT.

For both species, marketable and non-marketable fruit were quantified, and average individual fresh fruit weight and number were recorded. Non-marketable fruit were categorised by criteria. For muskmelon, the criteria for not being marketable were cracking, sun damage, malformation and <500 g fresh weight, according to [31]. For sweet pepper, the criteria were malformation, diseases, and discolouration, according to [32]. Equatorial and polar diameters of the fruits were measured in 10 randomly selected fruits in each cultivar and replicated plots of each species.

2.4. Fruit Quality Evaluation

Fruit quality in muskmelon was evaluated in the first harvest of the 2020 crop and in the only harvest of the 2021 crop. In the sweet pepper crops, fruit quality was evaluated in the fourth harvest of the 2020 crop, at 140 DAT, and in the second harvest of the 2021 crop, at 116 DAT. In both species, four fruits were randomly selected per cultivar and plot. The fruits were immediately taken to the laboratory where internal colour measurements were made on the flesh in muskmelon, and external colour measurements were made on the skin in sweet pepper. Colour measurements were made using a chroma meter (Minolta CR-400, Konica Minolta, Osaka, Japan) for determination of lightness (L*; L* = 0 yields black and L* = 100 indicates diffuse white), red–green axis (a*; negative values indicate green and positive values indicate red) and blue–yellow axis (b*; negative values indicate blue and positive values indicate yellow). Pitch angle (h) and chroma (C*) were calculated as $h = \arctan(a^*/b^*)$ and $C^* = \mathrm{sqrt}((a^*)^2 + (b^*)^2)$. The colour index (IC*) was calculated as $IC^* = (a^* \times 1000) / (L^* \times b^*)$. For muskmelon measurements, the fruits were cut into halves, and colour was measured in one half of the fruit at three points equidistant from the equatorial zone. In sweet pepper, colour was measured on the external skin at three points equidistant from the equatorial zone. Colour measurements were made using the same chroma meter Minolta CR-400.

Firmness of fruit was determined in the interior of one-half of the muskmelon fruit, and on the external skin of sweet pepper, at three equidistant points from the equatorial zone using a hand-held penetrometer (PCE-PTR 200N, PCE Ibérica S.L., Albacete, Spain). Units were expressed as newtons (N) of force.

To determine fruit total soluble solids (TSS), titratable acidity and pH, measurements were made in the juice of muskmelon pulp and in the juice of whole fruits of sweet pepper. In both crops, individual fruit samples were processed per cultivar and plot. In muskmelon, the skin and seeds were removed; in sweet pepper, the peduncle and seeds were removed. The juice was obtained using a domestic kitchen blender. TSS was determined with a digital refractometer (PAL-1, ATAGO CO., LTD, Tokyo, Japan) and expressed as %Brix. pH was determined with a hand-held pH meter (LAQUA PC110-K, Horiba, Ltd., Kyoto, Japan). Titratable acidity for both crops was determined using the following procedure: 10 mL of fruit juice was mixed with 50 mL of distilled water and a few drops of phenolphthalein indicator. The solution was titrated with 0.1 M NaOH until the indicator turned pink [33].

2.5. Data Analysis

Within each crop and year, differences in measured parameters between N treatments and cultivars were evaluated by factorial analysis of variance (ANOVA). Pairwise LSD post hoc tests were conducted when the N x Cultivar interaction or any of the main effects was significant at $p < 0.05$. The experimental layout consisted of a blocked design with four blocks arranged from the north to the south of the greenhouse; a blocking factor was included in ANOVA. If needed, variables were transformed to meet ANOVA assumptions. Statistical analysis was performed with STATISTICA 13.5 (TIBCO Software, Inc., Palo Alto, CA, USA).

3. Results

3.1. Effect of N and Cultivar on Total Yield and Percentage Fruit Discard

The total yield of muskmelon was significantly affected by both N and cultivar in the 2020 and 2021 crops, with no significant interaction between N and cultivar (Table S1). The total yield of the N1 treatment was significantly 40% less in the 2020 crop (Figure 1a) and 70% less in the 2021 crop (Figure 1b) than in N2 and N3 treatments, which were not significantly different from one another. Regarding cultivars, the most productive cultivar in the 2020 crop was Tezac, with a significant 16 and 27% higher total yield than Magiar and Jacobo, respectively (Figure 1a). In the 2021 crop, both Bosito and Magiar cultivars had a significant 20% higher total yield than Jacobo (Figure 1b). Regardless of the crop, Jacobo was the least productive cultivar (Figure 1a,b).

The total yield of sweet pepper was affected by N treatments in the 2020 crop but not in the 2021 crop (Table S1). In the 2020 crop, the total yield of the N1 treatment was significantly 59% less than the total yield of the N2 and N3 treatments, which were not significantly different (Figure 1c). There were no significant differences in total yield between cultivars in any of the two years (Table S1; Figure 1c,d).

As for fruit discard, in muskmelon, there were significant differences between N and cultivars in the percentage of fruit discard (Table S1). Fruit discard was 40% (2020 crop, Figure S1a) to 76% (2021 crop, Figure S1b) higher in the N1 treatment than in N2 and N3 treatments, which were not significantly different from one another in either year (Figure S1a,b). The cultivar with the highest percentage of fruit discard was Jacobo, in both years, with a 47% higher percentage of fruit discard than Tezac, in 2020 (Figure S1a), and a 65% higher percentage of fruit discard than Magiar and Bosito, in 2021 (Figure S1b).

There were no consistent differences in the percentage of fruit discarded between N treatments in the 2020 and 2021 sweet pepper crops (Table S1). By contrast, there were significant differences between cultivars in the percentage of fruit discarded in the 2021 crop but not in the 2020 crop (Table S1). In the 2021 crop, the percentage of fruit discarded was 28% lower in Machado than in Melchor and CLX PLRJ 731 cultivars (Figure S1d), which were not significantly different.

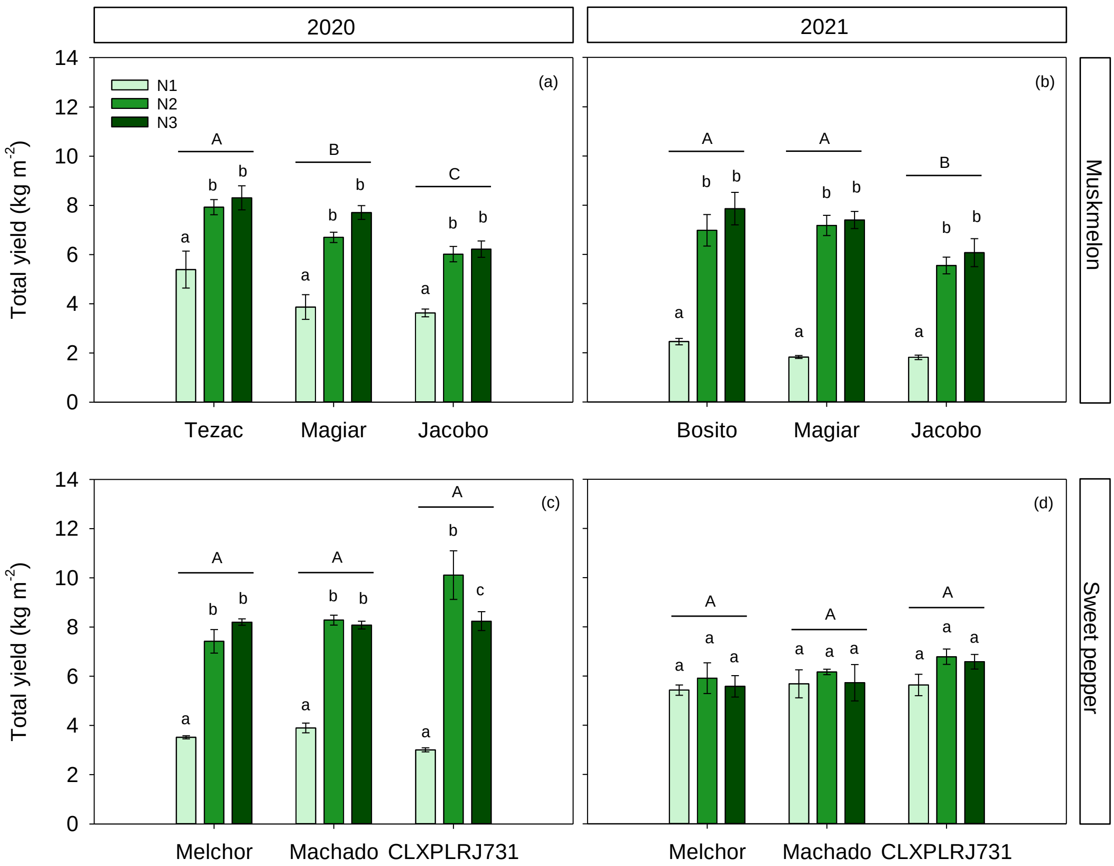

Figure 1. Total yield for three cultivars and three N treatments, for muskmelon (**a**,**b**) and sweet pepper (**c**,**d**) crops, conducted in 2020 and 2021 years. Different lowercase letters show significant differences between N treatments within each cultivar; different uppercase letters show significant differences between cultivars. Values are means ± SE.

3.2. Effect of N and Cultivar on Fruit Firmness and TSS

Nitrogen treatment significantly affected fruit firmness in the 2021 muskmelon crop, but not in the 2020 crop or in any of the sweet pepper crops (Table S2). In the 2021 muskmelon crop, fruit firmness was significantly higher in the N2 treatment than in the N1 and N3 treatments, which were not significantly different from one another (Figure 2b).

In both muskmelon and both sweet pepper crops, there were significant differences in fruit firmness between cultivars, regardless of N treatment (Table S2). Tezac had significantly lower fruit firmness than Magiar and Jacobo in the 2020 crop, whereas Bosito had higher fruit firmness than Magiar and Jacobo in the 2021 crop (Figure 2a,b). In sweet pepper, CLX PLRJ 731 had significantly lower fruit firmness than Melchor and Machado in both years (Figure 2c,d).

Nitrogen had a significant effect on fruit TSS in muskmelon and sweet pepper crops, except for the 2021 muskmelon crop where the effect was not significant (Table S2). The effect of N on fruit TSS was the opposite in muskmelon to sweet pepper (Figure 3). Whereas fruit TSS was significantly 12% higher in the N1 treatment in muskmelon (Figure 3a), fruit TSS was significantly 4.5% lower in the N1 treatment in sweet pepper (Figure 3c,d).

As for the differences between cultivars in fruit TSS, the Jacobo muskmelon cultivar had significantly higher TSS than Tezac, Bosito, and Magiar (Figure 3a,b). The CLX PLRJ 731 sweet pepper cultivar had lower fruit TSS than Melchor and Machado (Figure 3c,d).

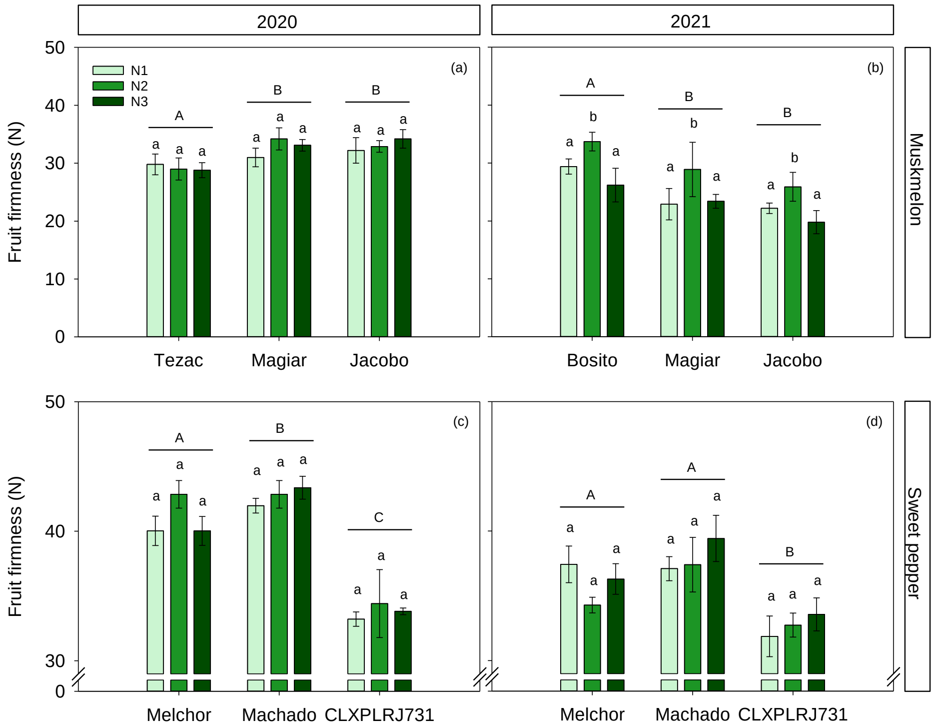

Figure 2. Fruit firmness for three cultivars and three N treatments, for muskmelon (**a**,**b**) and sweet pepper (**c**,**d**) crops, conducted in 2020 and 2021 years. In muskmelon, the measurements were internal; in sweet pepper, the measurements were external. Different lowercase letters show significant differences between N treatments within each cultivar; different uppercase letters show significant differences between cultivars. Values are means ± SE.

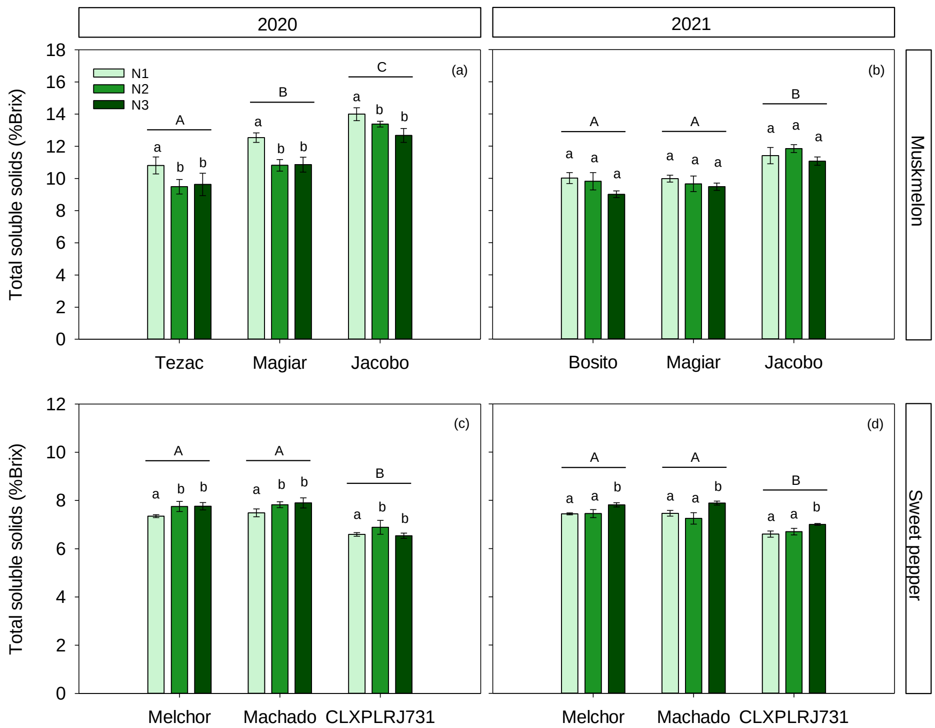

Figure 3. Fruit total soluble solids (TSS), expressed in %Brix, for three cultivars and three N treatments, for muskmelon (**a**,**b**) and sweet pepper (**c**,**d**) crops, conducted in 2020 and 2021 years. Different lowercase letters show significant differences between N treatments within each cultivar; different uppercase letters show significant differences between cultivars. Values are means ± SE.

3.3. Effect of N and Cultivar on Fruit Weight and Size

Nitrogen had an effect on fruit weight of muskmelon in both years (Table S3), regardless of the cultivar. Fruit weight was significantly 20% lower in the N1 than in the N3 treatment, with generally intermediate values in the N2 treatment (Figure 4a,b). By contrast, fruit weight of sweet pepper was not statistically affected by N treatments in any of the years and cultivars (Table S3); the exception being CLX PLRJ 731 in 2021 when higher fruit weight was obtained in the N2-N3 treatment than in the N1 treatment (Figure 4d).

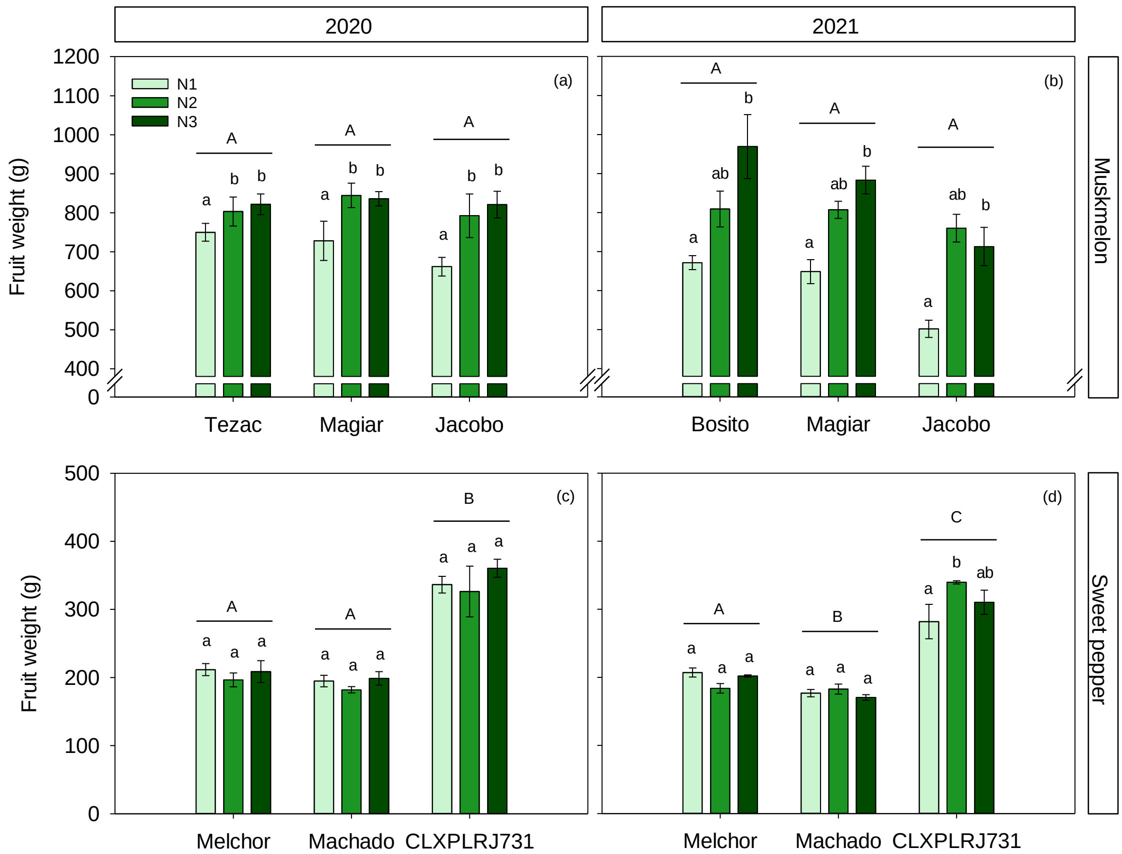

Figure 4. Fruit weight for three cultivars and three N treatments, for muskmelon (**a**,**b**) and sweet pepper (**c**,**d**) crops, conducted in 2020 and 2021 years. Different lowercase letters show significant differences between N treatments within each cultivar; different uppercase letters show significant differences between cultivars. Values are means ± SE.

There were no significant differences in fruit weight between cultivars of muskmelon in either crop (Table S3; Figure 4a,b). In sweet pepper, CLX PLRJ 731 had a significant 40% higher fruit weight than Melchor and Machado in both crops (Table S3; Figure 4c,d).

Nitrogen deficiency (N1 treatment) significantly reduced equatorial and polar diameters of muskmelon in both years (Table S3), compared to N2 and N3 treatments (Figures S2 and S3). However, in sweet pepper, N treatment did not significantly affect equatorial and polar diameters in any of the years (Table S3; Figures S2 and S3).

Regarding differences between cultivars in equatorial and polar diameters, there were contrasting results between muskmelon and sweet pepper crops (Table S3). There were no significant differences between cultivars in both equatorial and polar diameters in muskmelon in any of the years (Figures S2 and S3), except for Bosito which had a significantly higher equatorial diameter than Magiar and Jacobo in 2021 (Figure S2b). In sweet pepper, CLX PLRJ 731 had significantly higher equatorial and polar diameters than Melchor and Machado in both years, which were not significantly different (Figures S2 and S3).

3.4. Effect of N and Cultivar on Fruit Colour

In both muskmelon crops and in the 2020 sweet pepper crop, there were significant differences between N treatments in most colour parameters, except in a* (Table S4). For L*, b*, h and C*, values were generally significantly lower in the N1 treatment and higher in the N3 treatment, with intermediate values in the N2 treatment (Figures 5–7, S4 and S5). In the case of IC*, values were generally significantly higher in the N1 treatment and lower in the N3 treatment (Figure S6). In the 2021 sweet pepper crop, N had no significant effect on any colour parameter measured (Table S4).

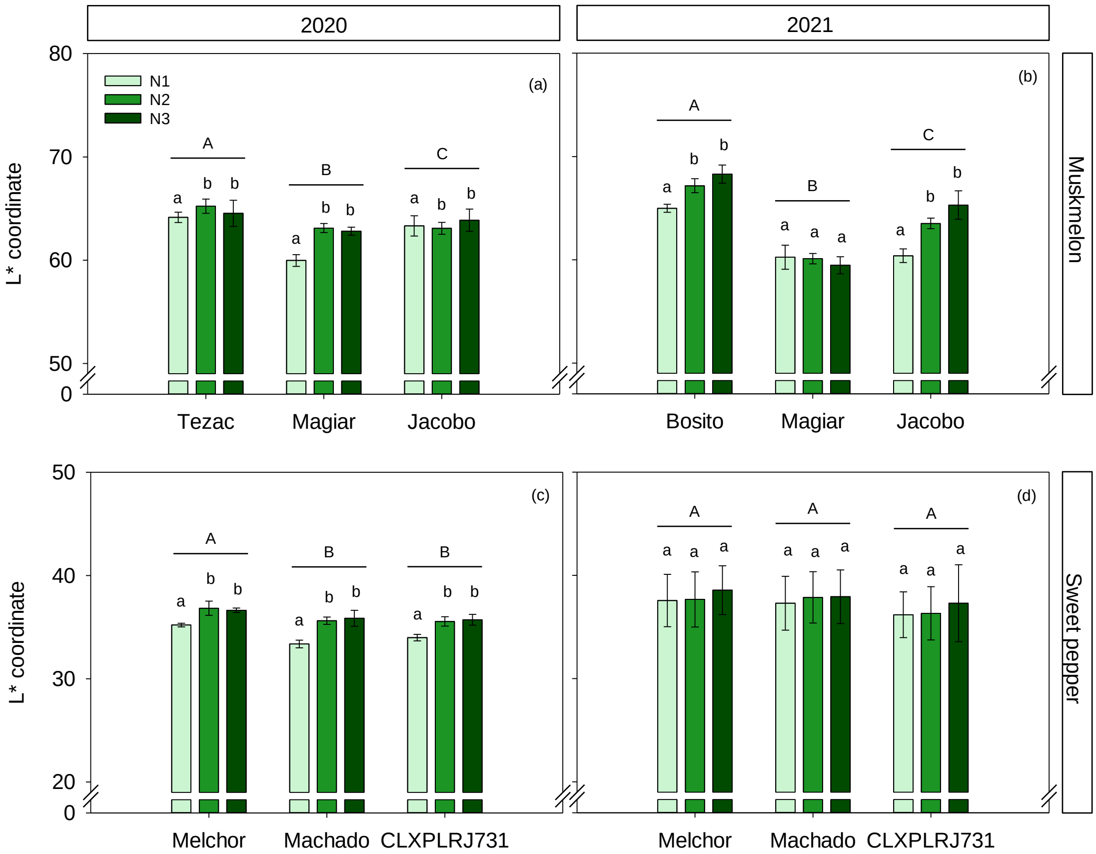

Figure 5. Fruit L* (lightness) for three cultivars and three N treatments, for muskmelon (**a**,**b**) and sweet pepper (**c**,**d**) crops, conducted in 2020 and 2021 years. Fruit measurements are internal for muskmelon and external for sweet pepper. Different lowercase letters show significant differences between N treatments within each cultivar; different uppercase letters show significant differences between cultivars. Values are means ± SE.

There were significant differences between cultivars in most colour parameters measured in 2020 and 2021 in both muskmelon and sweet pepper crops (Table S4). In muskmelon, Tezac, Bosito and Jacobo generally had higher L*, b*, h and C* than Magiar, which had generally lower values (Figures 5–7, S4 and S5). By contrast, Magiar had generally higher a* and IC* than Tezac, Bosito and Jacobo (Figure 6 and Figure S6).

In sweet pepper, Melchor had significantly higher a*, b*, and C* values than CLX PLRJ 731, both in 2020 and 2021, with Machado having intermediate values (Figures 6, 7 and S5). Melchor had slightly higher lightness (L*) values in 2020 but not in 2021 (Figure 5). There were no significant differences between cultivars in IC* values in any of the years (Figure S6).

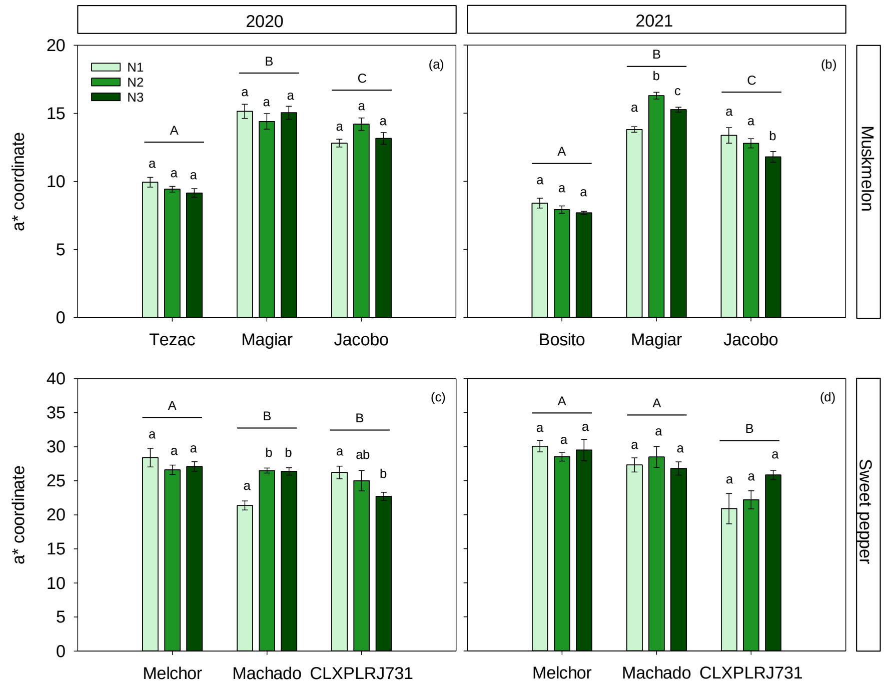

Figure 6. Fruit a* (red–green axis) for three cultivars and three N treatments, for muskmelon (**a**,**b**) and sweet pepper (**c**,**d**) crops, conducted in 2020 and 2021 years. Fruit measurements are internal for muskmelon and external for sweet pepper. Different lowercase letters show significant differences between N treatments within each cultivar; different uppercase letters show significant differences between cultivars. Values are means ± SE.

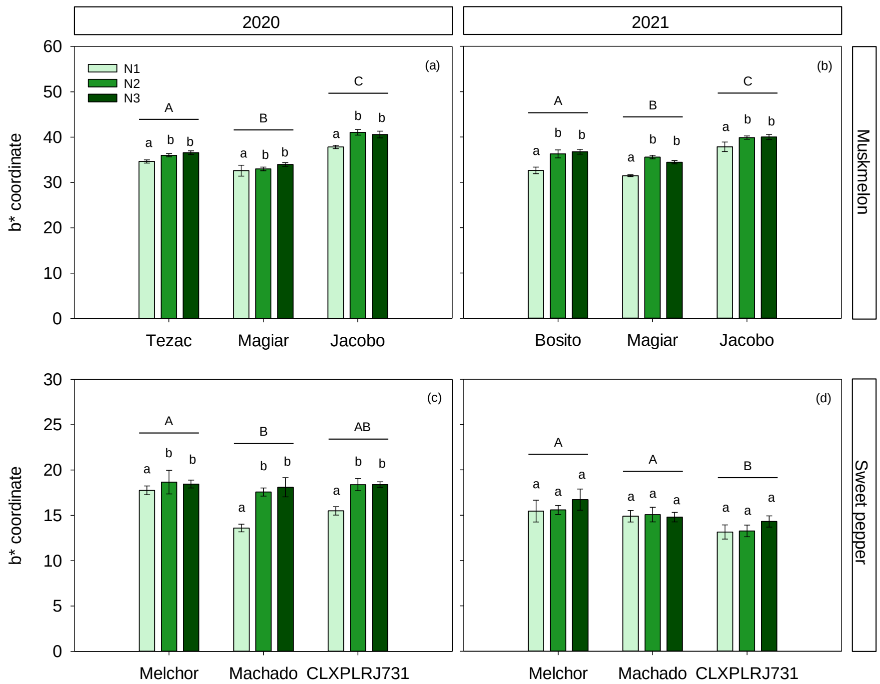

Figure 7. Fruit b* (blue–yellow axis) for three cultivars and three N treatments, for muskmelon (**a**,**b**) and sweet pepper (**c**,**d**) crops, conducted in 2020 and 2021 years. Fruit measurements are internal for muskmelon and external for sweet pepper. Different lowercase letters show significant differences between N treatments within each cultivar; different uppercase letters show significant differences between cultivars. Values are means ± SE.

4. Discussion

4.1. Nitrogen Effect on Yield

In this study, we detected yield reduction under N deficiency (i.e., N1 treatment) in both years of muskmelon crop, which was accompanied by fruits with lower weight and smaller size (i.e., lower equatorial and polar diameters). Overall, our findings suggest that an N application equivalent to the N2 treatment in the range of 228−302 kg N ha^{-1}, corresponding to an application of a nutrient solution of 8.0−8.3 mmol N L^{-1}, was sufficient to achieve a maximum yield in the range of 6.6−6.9 kg m^{-2} in muskmelon. This indicates that conventional N applications of the N3 treatment, of 14.0−14.6 mmol N L^{-1}, were excessive. However, the amount of mineral N existing in the soil at the beginning of the crop should be considered when managing the N fertilisation [34–36]. In the two present muskmelon crops, between 49 and 77 kg, N ha^{-1} was available in soil in the N2 treatment at the beginning of the crop. Comparison of yields of the present study with those of the literature showed that our muskmelon crops were very productive; [15] reported that N applications of 130–180 kg N ha^{-1} were associated with yields of 3.8 kg m^{-2}.

The total yield of sweet pepper was also reduced under N reduction (i.e., N1 treatment) but only in 2020. In sweet pepper, fruit weight and size were not reduced under deficient N. A maximum total yield of 8.5 kg m^{-2} was obtained in the N2 treatment with an N application of 425 kg N ha^{-1}, corresponding to a concentration of the nutrient solution of 8.4 mmol N L^{-1}. This is a slightly higher yield and lower N application than the results of [37] and [36], where the maximum yield of sweet pepper of 7.5 and 7.0 kg m^{-2} was obtained with N applications of 519 kg N ha^{-1} (9.7 mmol N L^{-1}) and 530 kg N ha^{-1} (10 mmol N L^{-1}), respectively. In 2020, there was very little mineral N in the soil (0–0.4 m) at the beginning of the crop (i.e., 17 kg N ha^{-1} in the N2 treatment). As with muskmelon, the findings of the 2020 crop indicate that conventional N applications of the N3 treatment, of 14.2 mmol N L^{-1}, were excessive for sweet pepper.

Unlike the 2020 crop, the total yield of sweet pepper was not affected by N treatments in the 2021 crop, with an average yield of 6.0 kg m^{-2} for the three N treatments that supplied very different amounts of N (Table 1). This was most likely caused by the substantial amount of mineral soil N present at the beginning of the crop (i.e., 340 kg N ha^{-1}), which presumably contributed significantly to the N nutrition of the crop in the N1 treatment There was a delay in preparing the fertigation system of the greenhouse used for this crop that prevented N leaching irrigations being given immediately before the crop.

There were consistent results of fruit discard increasing under N reduction (i.e., N1 treatment) of both years of muskmelon crop, with smaller fruits and fruits with more external flaws. It can be concluded that deficient N application led to malformed and smaller muskmelon fruit. These observations coincide with several reports where low N application increased percentages of non-marketable fruit in the muskmelon [38–40]. However, in the case of sweet pepper, fruit discard was not significantly affected by N treatment in the 2020 crop, but the lack of deficient N treatments in the 2021 crop prevents drawing any conclusion on the sensitivity of fruit discard to N deficiency in sweet pepper.

4.2. Nitrogen Effect on Fruit Quality

There were inconsistent effects of N treatments on fruit firmness in the two muskmelon crops. Such contrasting results were also found in the literature. While [40] found that increasing N addition from 0 to 165 kg N ha^{-1} did not affect fruit firmness of netted melon, [41] reported that increasing N from 0 to 150 kg N ha^{-1} decreased fruit firmness of yellow melon in open field conditions. In the case of sweet pepper, fruit firmness was not affected by increasing N application in the 2020 crop, which is consistent with reports by [42] and [43]. Unfortunately, the lack of N deficiency in the 2021 sweet pepper crop precluded shedding light into this issue with two replicated crops. The results of the present study and of the literature suggest that fruit firmness is not consistently influenced by the amount of N fertiliser in muskmelon. The lack of consistent effects of N on fruit firmness of muskmelon may indicate that environmental and/or agronomical factors, other than N addition, are responsible for changes in the fruit firmness [31,44–46].

An average value of 11.5 %Brix was obtained in the N1 treatment in the 2020 and 2021 muskmelon crops. Considering that the minimum TSS reference value for commercialisation is 10 %Brix [40], fruits of the N1 treatment would be very acceptable for consumers. It is noteworthy that the TSS of fruits in the N2 and N3 treatments were also above the threshold value of 10 %Brix, with average values of 10.8 and 10.5 %Brix, respectively, indicating that higher N fertilisation also produced fruit with acceptable consumer quality. Other studies reported no response of TSS to increasing N application, from 0 to 165 kg N ha^{-1} [40,41], and from 0 to 300 kg N ha^{-1} [47]. It is possible that the lack of effect of increasing N addition on TSS in the literature was caused by an insufficient range of N application, unlike in the present study with larger ranges of N application. Overall, it can be concluded that lower N application resulted in slightly sweeter muskmelon fruits.

For sweet pepper fruit, the TSS of the N3 treatment averaged 7.5 %Brix. Taking into account that the TSS reference values for commercialisation of red peppers are in the range of 7–8 %Brix [42,48], the N3 treatment produced peppers with acceptable marketable quality. Concurring with our findings, values of 8 %Brix were found by [42] with an application of 9.8 mmol N L^{-1}; this concentration was intermediate between the concentrations of the N2 (8.3 mmol N L^{-1}) and N3 (14.2 mmol N L^{-1}) treatments of the present study. In our study, the TSS of fruits of the N1 treatment averaged 7.2 %Brix, a value that fits within the optimal range of 7–8 %Brix for commercialisation of red pepper. Values of TSS of the N1 treatment indicate that lower N fertilisation also produced peppers with acceptable quality for consumers. Taking the results of fruit TSS of muskmelon and sweet peppers as a whole, it can be concluded that N addition plays a minor role in determining the fruit TSS [49–51].

For muskmelon, an intense orange colour of fruit flesh is a quality attribute highly valued by consumers [52]. However, the a* coordinate that measures the red–green axis was not affected by N treatments, indicating that N application does not affect this important quality attribute in muskmelon. Lightness (L*) and the yellow–blue axis (b* coordinate) increased with N addition, concurring with the findings of [40] who reported significant differences in lightness (L*) with increasing N applications from 0 to 165 kg N ha^{-1}. The increasing values of L* with N addition can be associated with increasing contents of pigments such as chlorophylls [53].

For sweet pepper, low N application reduced fruit colour lightness (L*) and the yellow–blue axis (b* coordinate) in the 2020 crop. These results are consistent with the findings of [54] who reported that N deficiency resulted in more yellowish fruits of red-fruit sweet pepper. In the 2021 sweet pepper crop, there was no effect of N deficiency on fruit colour presumably because the large amount of mineral soil N affected the N1 treatment so it was not sufficiently deficient to affect fruit colour. [43] reported that a moderately N deficient treatment of 7 mmol L^{-1} did not affect fruit colour parameters.

4.3. Cultivar Effect on Yield

Ref. [55] reported differences in yield between melon cultivars attributable to the number of fruits per vine and fruit weight. In the present study, the muskmelon Tezac and Bosito were the cultivars with highest total yields but there were no differences between cultivars in mean fruit weight and in the equatorial and polar diameters of the fruits, regardless of the crop. Differences in yield between cultivars were due to more fruit numbers in the Tezac and Bosito cultivars. Additionally, Tezac and Bosito were the cultivars that had lower percentages of fruit discard.

For sweet pepper, all three cultivars have comparable total yield but fruits of CLX PLRJ 731 were heavier and with much larger polar diameter. These results with CLX PLRJ 731 were not surprising given the longer shape of this lamuyo-type variety, compared to the shorter California-type Melchor and Machado cultivars. Because of the absence of differences in the total yield with the other cultivars, it is very likely that CLX PLRJ 731 produced lower number of fruits per plant. It is worth mentioning that the percentage of fruit discarded was lower in Machado than in Melchor and CLX PLRJ 731 because of the lower occurrence of undersized fruits and fruit malformation.

4.4. Cultivar Effect on Fruit Quality

For sweet pepper, the lamuyo-type CLX PLRJ 731 cultivar had lower fruit firmness than the California-type Melchor and Machado, with Machado having the highest fruit firmness. Higher fruit firmness of Machado is likely to be beneficial for transporting fruit [56]. This is very relevant for vegetable production in SE Spain from where much of the production is exported to Northern Europe [57,58].

Within the three muskmelon cultivars, Jacobo had the highest fruit TSS with an average value of 12.4 %Brix. In a study that evaluated the fruit quality of melon cultivars grown in a greenhouse [56], cultivars with TSS of more than 10 %Brix were considered to have adequate quality. It is important to note that the Jacobo cultivar in the current study exceeded this target value and that the cultivar Magiar had a TSS of 10.6 %Brix. The Tezac and Bosito cultivars had TSS values of 10.0 and 9.6 %Brix, respectively. These results suggest that Jacobo and then Magiar would have the sweetest taste. For sweet pepper, the California-type Melchor and Machado cultivars had higher fruit TSS than the lamuyo-type CLX PLRJ 731, with average values of 7.6, 7.6 and 6.7 %Brix, respectively. In Melchor and Machado, the TSS values were within the recommended values for red peppers of 7–8 %Brix [42,48]. CLX PLRJ 731 had TSS values below the acceptable range for the commercialisation of red peppers.

Magiar was the muskmelon cultivar with the highest a* coordinate (red–green axis), which generated a more intense orange pulp colour. According to [52], a* values >15 is preferred by consumers, whereas a* values ≤10 are associated with a pale orange colour and are undesirable to consumers. In the present study, the average a* values of Magiar and Jacobo were 15.0 and 13.0, respectively, compared to average values of 9.5 and 8.0, for Tezac and Bosito, respectively. It is likely that consumers will prefer the fruits of Magiar and Jacobo because of their more intense orange colour.

In sweet pepper, Melchor tended to have slightly higher average a* values (i.e., 28.36) than Machado (26.14) and CLX PLRJ 731 (23.81). The higher a* value in Melchor indicated a stronger reddish colour [48,59], which is a characteristic desired by consumers [32]. In the case of L*, the Melchor cultivar had higher values in 2020 thus indicating higher lightness and likely more preference by consumers. However, the larger variability in L* values in all cultivars in 2021 likely precluded the detection of differences between cultivars.

5. Conclusions

For most of the parameters evaluated in muskmelon and sweet pepper crops, the effects of N, when significant, occurred consistently regardless of cultivar. In both muskmelon and sweet pepper, the N2 treatment provided sufficient N to achieve maximum yield. In the case of muskmelon, deficient N application resulted in an increased percentage of fruit discard, mostly due to malformation and small size. In contrast, in sweet pepper fruit discard was insensitive to N deficiency in the 2020 crop. Most of the fruit quality parameters were not consistently affected by N. This was particularly true for fruit firmness, TSS and colour analysis. In particular, the N addition had no effect on increasing a* values (i.e., red–green axis), which is related to stronger orange flesh colour in muskmelon, and more reddish peppers in sweet pepper. The N addition increased lightness (i.e., L*) values in both species, likely because of rising contents of chlorophyll pigments. There was a general tendency for fruit TSS to slightly decrease with N addition in muskmelon, and to slightly increase with N addition in sweet pepper, indicating that the N addition played a minor role in determining fruit TSS in these species. Overall, these results indicated that conventional N applications in the range of 14 mmol N L^{-1} were excessive and did not improve yield or fruit quality. Importantly, these findings occurred regardless of the cultivar. In the context of overuse of N fertilisers in intensive crops of South-Eastern

Spain, fertigation of muskmelon and sweet pepper crops may be reduced to levels of 8.0–8.4 mmol N L^{-1} without losses in yield or fruit quality.

Regarding cultivar effects, there were differences in total yield between cultivars in muskmelon but not in sweet pepper. In muskmelon, cultivar differences in yield were most likely due to differences in fruit number. There were also differences between cultivars in fruit quality parameters such as TSS and a* values, in both muskmelon and sweet pepper. Cultivars with higher TSS and a* value will likely be more desirable for consumers because of the sweeter taste and more intense orange colour in muskmelon and reddish colour in sweet pepper.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy12092230/s1, Figure S1: percentage of fruit discard; Figure S2: fruit equatorial diameter; Figure S3: fruit polar diameter; Figure S4: fruit hue angle (h); Figure S5: fruit chroma (C*); Figure S6: fruit colour index (IC*); Table S1: results of analysis of variance of yield and percentage discard fruit; Table S2: results of analysis of variance of fruit firmness and TSS; Table S3: results of analysis of variance of fruit weight and equatorial and polar fruit diameters; Table S4: results of analysis of variance of internal fruit colour.

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