Appendix 5.20

Paper in press

Title: Domestication potential of Marula (*Sclerocarya birrea* subsp *caffra*) in South Africa and Namibia: 1. Phenotypic variation in fruit traits

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Domestication potential of Marula (*Sclerocarya birrea* subsp *caffra*) in South Africa and Namibia: 1. Phenotypic variation in fruit traits.

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ABSTRACT

Twenty four ripe fruits were collected from each of 55 marula (*Sclerocarya birrea*) trees in Bushbuckridge, South Africa and from 63 trees from the North Central Region of Namibia. The South African trees were in farmers's fields (20), communal land (29) and natural woodland (14), at three sites: Acornhoek road, Allandale/Green Valley and Andover/Wits Rural Facility. The Namibian trees were all from farmers' fields in three areas: North east (20), North west (10) and West (25). The fruits were partitioned into skin and flesh/juice. Each component of each fruit was weighed fresh separately. The data provides a good understanding of the extent of the variation found in marula fruits of different trees, and of the dry matter partitioning between skin and flesh/juice mass.

Namibian fruits were found to be significantly larger than those from South Africa, due to their greater pulp mass, especially the flesh/juice component. In South African fruits, those from Farmers' fields were significantly larger in all components. In Namibia, fruits were larger from the North west. Within each sample there was highly significant and continuous variation between trees in the pulp and flesh/juice mass, indicating the potential for selection of trees producing larger products. The fruits of the Namibian trees were compared with the fruits from one superior tree ('Namibian Wonder').

INTRODUCTION

Sclerocarya birrea (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro is one of the traditionally important indigenous fruits of southern Africa, which in recent years has also become commercially important as its fruits and other products have entered local, regional and international trade (Shackleton *et al*., 2002; Wynberg *et al*., in press). With this growing commercial importance have emerged several domestication initiatives. The first was by Holtzhausen *et al.* (1990) of Pretoria University who started to develop cultivars from 'plus-trees' taken from the wild using grafting techniques. The second initiative was by Veld Products Research in Botswana (Taylor *et al*., 1995; 1996), while the third was an external domestication programme, initiated by Ben Gurion University in Israel, using material obtained in southern Africa and planted in the Negev Desert (Nerd and Mizrahi 1993; Mizrahi and Nerd, 1996). A fourth programme was launched in 1995 by the International Centre for Research in Agroforestry (ICRAF), now the World Agroforestry Centre, with a participatory mandate, in which subsistence farmers are the planned beneficiaries of the domestication activities (Maghembe, *et al*., 1995; 1998). Rangewide germplasm collections of *S. birrea* and *Uapaca kirkiana* have been made as the first step in a domestication strategy (Leakey and Simons, 1998). These collections provide material for conservation and future utilisation.

In many countries, non-timber forest products (NTFPs) are an under-utilised resource, and it is only in recent years that domestication projects for agroforestry trees have been initiated (Leakey *et al* 1996). However, without parallel efforts to promote the commercialisation of these products, domestication is unlikely to yield the expected benefits in terms of poverty alleviation, and there is a need for agroforesters to work closely with the private sector (Leakey, 1999). The present study, as part of a resource inventory, quantifies the phenotypic variation in fruit traits in marula (*S. birrea* ssp. *caffra*), within the framework of a broader project examining the benefits and opportunities for domesticating and commercialising the fruits and kernel oil of marula in South Africa and Namibia. Recent collections of marula fruits and nuts from individual trees in Makueni district of Kenya have been analysed for a wide range of nutritional compounds and minerals. The skin and flesh was found to vary considerably in the vitamin C content (85-319mg/100g), while the kernels were rich (56-64%) in oils (Thiong'o *et al*., 2002).

METHODS AND MATERIALS

Marula fruits fall from the tree just before they ripen. Ripe, unblemished fruits were collected from beneath the crown of marula trees in villages in Limpopo Province, South Africa (Bushbuckridge) and Namibia (North Central Region), between 21st January and 5th February 2002 (Table 1). In South Africa, marula trees were found in farmers' fields, in communal grazing land, and in natural woodland, while in Namibia, fruiting trees were only found in farmers' fields. In general, fruits were usually plentiful and so were collected at random sampling from four quadrants (6 fruits per quadrant), according to the procedures developed by Leakey *et al.* (2000). Fruits from each tree were separately bagged and labelled. As soon as possible (usually 2-3 days later), the fresh fruits were weighed using a 0.1g electronic balance. Keeping the fruits in the same order, the skins were then peeled off and weighed, while the nuts, still in the same order, were soaked and scrubbed to remove the flesh before being set in the sun to dry for about 10 hours. When dry, the nuts were weighed and numbered so that their identity was maintained for subsequent cracking and kernel removal (Leakey *et al*., in press). Flesh mass were derived by difference (Fruit - skin - nut = flesh).

In addition, one fruit sample was collected from the Mhala Development Centre (MDC), a project of the Mineworker's Development Agency in Bushbuckridge that is processing fruits for fruit juice and for kernel oil. A further sample from a superior tree (‘Namibian Wonder’) was analysed in the same way. The origin of this tree is not disclosed in order to protect the villagers’ rights to this germplasm.

Table 1. Origins of trees sampled in South Africa and Namibia, by village and land use.

	Natural woodland	Communal land	Farmers fields	Total
South Africa				
Bushbuckridge				
Acornhoek road		29 trees	6 trees	35 trees
Allandale			10 trees	10 trees
Green Valley			4 trees	4 trees
Andover	11 trees			11 trees
Wits Rural Facility	3 trees			3 trees
TOTAL	**14 trees**	**29 trees**	**20 trees**	**63 trees**
Namibia				
North west				
Omanjoshi			7 trees	7 trees
Omankango			9 trees	9 trees
Okamukwa			4 trees	4 trees
North east				
Onangwe			8 trees	8 trees
Oilyateko			1 tree	1 tree
Elope			1 tree	1 tree
West				
Tsandi: - Otjito			4 trees	4 trees
Tsandi: - Omukoko			6 trees	6 trees
Onesi: – Otjeviya			4 trees	4 trees
Onesi: - Otjihawu			2 trees	2 trees
Eunda			2 trees	2 trees
Eunda: – Oukwanangaya			2 trees	2 trees
Ongosi			5 trees	5 trees
TOTAL	**0**	**0**	**55 trees**	**55 trees**

Analysis of Variance, Duncan’s Multiple Range tests, and tests for skewness and kurtosis have been using SPSS 10.0 for Windows.

RESULTS

Variation between sites

Comparison of mean values between South Africa and Namibia.
The significantly greater mean fruit mass of Namibian fruits is attributable to the greater mass of pulp, as opposed to nut (Table 2). In turn, the greater pulp mass is attributable to a greater mass of fresh fruit flesh and juice, as opposed to skin (Table 2). Although there were differences in the time between collection and laboratory

processing of the fruit samples in South Africa (1 day) and Namibia (2-3 days) which could have resulted in greater ripening of the Namibian samples, and hence the juiciness of the samples (ie. partitioning of water between flesh and skin), it is unlikely that there could have been any change in the overall fresh weight of the pulp as the fruits were stored in sealed polythene bags.

Comparison of mean values between sites in South Africa
There were highly significant differences in mean fruit, skin, pulp, flesh/juice mass, between sites in South Africa (Table 3). Fruits from Allandale were typically the largest. The trees from Acornhoek road were located in both farmer's fields and communal land, while those from Allandale and Green Valley were only in farmer's fields. Trees from Andover and Wits Rural Facility were in natural woodland. An analysis by land use follows.

Comparison of mean values between land uses in South Africa
The mean mass of fruits, pulp, flesh/juice and skin and were significantly greater in fruits from farmers' fields than from communal land or natural woodland in South Africa (Table 4).

Comparison of mean values between sites in Namibia
There were significant differences in mean skin, pulp, flesh/juice mass, between areas in Namibia, but not in fruit mass (Table 5).

Variation within sites
Within all sites, in both South Africa and Namibia, there was highly significant variation between individual trees in all the morphological traits of fruits, that were measured.

Fruit mass
There was highly significant and continuous variation in fruit mass within each site in both South Africa and Namibia (Figures 1a and b), which was most evident in samples in excess of five trees. The fruits of 'Namibian Wonder' were, however, very much heavier (69.9g) than those of any other tree assessed (largest was N38 at 41.7g). The fruits of 'Namibian Wonder', which ranged in mass from 57-79g were heavier than any reported to date, exceeding those developed as cultivars by Holtzhausen *et al*. (1990). Assessment of the fruits passing through the MDC fruit juice processing unit, indicated that the fruits brought to this market are comparable in mass with the best of the fruits sampled in this study, indicating that the women discarded the smaller fruits.

When the data from South African trees was aggregated by land use, the mean fruit mass of fruits from farmers' fields was significantly greater than that from communal land or natural woodland, there also being a significant difference between the populations outside farmers' fields (Figure 2). This comparison cannot be made in Namibia, as all the trees sampled were in farmers' fields.

Pulp mass
Pulp mass is the major component of fruits (Figure 3a and b) and showed highly significant and continuous variation within site samples, in a sequence similar to that for fruit mass. The pulp component of marula fruits is approximately 50% skin and

50% flesh and juice. In the South African fruits, skin was the larger proportion, while in Namibia, flesh and juice made the larger proportion (Figures 4a and b); this may reflect differences in ripeness, due to the longer time before Namibian fruits were weighed and processed. Alternatively it may reflect the greater proximity to the watertable, in the Cuvelai drainage system of the Owambo Basin of Namibia, which drains into the Etosha Pan.

The fruits of 'Namibian Wonder' had very much greater pulp mass (more than twice the mean pulp mass) than the fruits of other trees (Figure 4b).

Frequency distribution
The data for fruit mass of each tree in each site displayed considerable variance about its mean. The frequency distribution of this data, and of the overall site mean were close to a normal distribution (Table 6). When the data for South African trees were aggregated by land use, the frequency distributions for natural woodland was also close to normality (skewness = -0.03 to 0.83), but that for communal lands and farmers fields had a greater tendency towards being positively skewed (Table 6), the latter also having some bi-modality. In a similar way, the distribution pattern of the same traits in Namibia, was close to normal, but with some degree of bimodality in fruit mass from the populations from the North east and North west (Table 6).

DISCUSSION

The very considerable tree-to-tree variation in fruit characteristics in marula are consistent with results from other indigenous fruit trees, such as *Irvingia gabonensis* (Atangana *et al*., 2001) and *Dacryodes edulis* (Waruhiu, 1999; Leakey *et al*., 2002) in west and central Africa. As in the case of these moist forest species of west and central Africa, this variation, coupled with the considerable market opportunities, indicates that there are domestication opportunities for marula, as has already been recognised (Holtzhausen *et al*., 1990; Taylor *et al*., 1996; Mizrahi and Nerd, 1996; Maghembe, *et al*., 1998). However, this study quantifies the variation in dry matter partitioning between constituent parts of the fruits for the first time, and provides good fundamental knowledge about the range of variation in several important traits across geographically separated, as well as environmentally and culturally different sites. This allows an analysis of the relationships between different commercially traits of importance to the development of cultivars that can be used to determine 'ideotypes' that maximise the Harvest Index across several different fruit traits, and hence to identify potential cultivars for cultivation that could meet the needs of farmers with proximity to different markets.

It is clear from this study of the phenotypic (tree-to-tree) variation in populations in South Africa and Namibia (Figures 16 and 17), and that there is very considerable opportunity to identify individual trees with fruit characteristics well above the average of the species. While this is evident from the range of continuous variation identified in each of the populations studied, populations of only 14-63 trees, the potential is really highlighted by the discovery of 'Namibian Wonder', a much more rare member of the population. Such extreme examples of phenotypic variation are only found at far greater selection intensities. In the present study, the Namibian populations seems to have greater promise of superior trees than that of South Africa, but the geographical range surveyed in South Africa was considerably narrower than in Namibia, although neither survey was comprehensive.

ADD something about fruit prices and uses

In this study, a sample of the fruits passing through the MDC juicing process were sampled and characterised. It was found (Figure 3a) that the women were processing fruits representative of the best 84% of the trees in the area (= they had discarded the worst 16%). Through domestication, they could improve their trees and produce fruits equivalent to the best 5% in the area. This would reduce the labour involved in juicing the fruits, increase the proportion of the pulp extracted (nb. this project has identified that the women are not recovering a high proportion of the juice – Mander, pers. comm.), and with appropriate selection could probably improve the flavour of the product. Interestingly, the 'Amarula' factory of Distell Corporation use both the skin and the pulp in their process, so maximising the product they obtain from the fruits. An opportunity for the future would be to add an assessment of the genetic and non-genetic (consequences of storage and processing) organoleptic (flavour and fragrance) properties of different fruit samples as these are important commercially in the juice and liqueur industry. It would be important to interact with commercial companies to determine which properties are desirable and which are undesirable.

Studies of the frequency distribution of fruit and kernel trait data in *Dacryodes edulis* and *Irvingia gabonensis* in West Africa, similar to that reported here, have indicated that farmers, by their own procedures of genetic selection (truncated selection), have made a 40-65% gain in fruit mass (Leakey *et al*., in press a). A similar analysis with marula, is not conclusive, but there are certainly some results that suggest that a similar process of farmer domestication is underway in southern Africa. For example, several data sets (eg. fruit mass from trees in farmers' fields – Table 6) are positively skewed (with a tendency to bimodality), with a tail of unusually large fruits. This contrasts with more normally distributed data from trees in natural woodlands. This suggests that farmers, through truncated selection over several generations, have achieved at least the second stage of domestication (Leakey *et al*., in press b).

Interestingly, other studies within this project (Shackleton, C. pers. comm.) have found large differences in marula tree fruit yield between trees in farmers' fields and in communal land and natural woodland. Some of these trees were the same as in this study and in these trees the mean yield/tree from 13 trees in crop fields was 33,187 fruits, while that from 12 trees in natural woodlands was only 6135 (Shackleton, C. pers. comm.). It is not clear to what extent these differences in fruit yield represent genetic selection or cultivation and reduced competition in farmers' fields from other plants, but the frequency distribution ADD results suggest that subsistence farmers in southern Africa have started to domesticate their indigenous fruit trees.

Site differences may reflect differences in the environment, in anthropogenic activity or evolutionary responses to different survival/regeneration pressures.

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FIGURE LEGENDS

Figure 1a. Fruit mass (g) of marula (*Sclerocarya birrea*) by site in Bushbuckridge, South Africa

Figure 1b. Fruit mass (g) of marula (*Sclerocarya birrea*) by site in North Central Region, Namibia

Figure 2. Fruit mass of marula (*Sclerocarya birrea*) by land use in Bushbuckridge, South Africa

Figure 3a. Nut and pulp mass of marula (*Sclerocarya birrea*) in Bushbuckridge, South Africa (in order of fruit mass)

Figure 3b. Nut and pulp mass of marula (*Sclerocarya birrea*) in North Central Region, Namibia (in order of fruit mass)

Figure 4a. Skin and flesh/juice mass of marula (*Sclerocarya birrea*) in Bushbuckridge, South Africa (in order of fruit mass)

Figure 4b. Skin and flesh/juice mass of marula (*Sclerocarya birrea*) in North Central Region, Namibia (in order of fruit mass)

ADD graphs of frequency distribution??

Table 2. Comparison of marula (***Sclerocarya*** *birrea*) fruit traits between South Africa and Namibia

Trait	South Africa	Namibia	Probability
Mean fruit mass	20.11	26.68	P = <0.001
Mean skin mass	8.91	9.60	P = <0.001
Mean flesh mass	7.24	13.37	P = <0.001
Mean pulp mass	16.15	22.23	P = <0.001

Table 3. Comparison of marula (***Sclerocarya*** *birrea*) fruit traits across South African sites

Trait	Site				Probability
	Acornhoek road	Andover and Wits Rural Facility	Allandale	Green Valley	
Mean fruit mass	18.8 c	19.3 c	24.8 a	22.1 b	P = <0.001
Mean skin mass	8.6 b	8.6 b	10.1 a	9.8 a	P = <0.001
Mean flesh mass	6.5 c	6.5 c	10.4 a	8.7 b	P = <0.001
Mean pulp mass	15.0 c	15.1 c	20.5 a	18.5 b	P = <0.001

Table 4. Comparison of marula (*Sclerocarya birrea*) fruit traits across land use systems in South Africa

Trait	Site			Probability
	Farmer's fields	Communal land	Natural woodland	
Mean fruit mass	23.60 a	18.03 c	19.34 b	P = <0.001
Mean skin mass	9.92 a	8.33 b	8.65 b	P = <0.001
Mean flesh mass	9.50 a	6.02 c	6.48 b	P = <0.001
Mean pulp mass	19.42 a	14.35 c	15.13 b	P = <0.001

Table 5. Comparison of marula (***Sclerocarya*** *birrea*) fruit traits across Namibian sites

Trait	Site			Probability
	North west	North east	West	
Mean fruit mass	26.89 a	25.49 a	26.96 a	P=0.137
Mean skin mass	9.52 b	10.28 a	9.40 b	P=0.003
Mean flesh mass	13.26 a	11.19 b	14.29 a	P = <0.001
Mean pulp mass	22.78 a	21.47 b	22.10 ab	P=0.094

Table 6. Frequency distributions of marula (*Sclerocarya birrea*) fruit trait data from different sites and land uses in South Africa and Namibia
Skewness / Kurtosis = 0 = normality (+ skewness = a long tail of high values - skewness = a long tail of low values
+ kurtosis = tails longer than normality - kurtosis = tails shorter than normality)

South Africa by site

	Allandale and Green Valley				**Andover and WRF**				**Acornhoek Rd**			
	Mean	SE	Skewness	Kurtosis	Mean	SE	Skewness	Kurtosis	Mean	SE	Skewness	Kurtosis
Fruit mass	24.00	0.35	0.78	0.64	18.84	0.23	0.96	1.78	19.34	0.31	0.43	0.07
Skin mass	10.03	0.16	1.15	1.38	8.56	0.09	0.80	0.88	8.65	0.14	0.44	-0.09
Flesh mass	9.93	0.18	0.66	1.16	6.45	0.13	0.72	0.84	6.48	0.18	0.53	0.35
Pulp mass	19.96	0.30	0.76	0.63	15.01	0.20	0.88	1.47	15.13	0.27	0.36	-0.03

South Africa by land use

	Farmers fields				**Communal land**				**Natural woodland**			
	Mean	SE	Skewness	Kurtosis	Mean	SE	Skewness	Kurtosis	Mean	SE	Skewness	Kurtosis
Fruit mass	23.60	0.32	0.97	0.86	18.03	0.23	0.48	0.19	19.34	0.31	0.43	0.07
Skin mass	9.92	0.13	1.07	1.21	8.33	0.10	0.80	0.95	8.65	0.14	0.44	-0.09
Flesh mass	9.50	0.17	0.68	0.60	6.02	0.13	0.31	-0.41	6.48	0.18	0.53	0.35
Pulp mass	19.42	0.28	0.85	0.57	14.35	0.20	0.52	0.43	15.13	0.27	0.36	-0.03

Namibia by site

	Namibia NE				Namibia NW				Namibia W (excluding Namibian Wonder)			
	Mean	SE	Skewness	Kurtosis	Mean	SE	Skewness	Kurtosis	Mean	SE	Skewness	Kurtosis
Fruit mass	24.49	0.54	0.29	-0.82	26.89	0.38	0.66	0.33	25.24	0.34	0.53	0.24
Skin mass	10.28	0.21	0.40	-0.24	9.52	0.14	0.63	0.24	8.98	0.13	0.86	0.95
Flesh mass	11.19	0.35	0.22	-0.95	13.26	0.24	0.48	0.29	12.50	0.21	0.55	0.58
Pulp mass	21.47	0.51	0.23	-0.93	22.78	0.35	0.58	0.30	21.42	0.30	0.41	0.20

South Africa and Namibia

	South Africa				Namibia				South Africa and Namibia			
	Mean	SE	Skewness	Kurtosis	Mean	SE	Skewness	Kurtosis	Mean	SE	Skewness	Kurtosis
Fruit mass	20.11	0.17	0.74	1.01	26.68	0.28	1.60	4.92	23.21	0.17	1.58	5.45
Skin mass	8.91	0.07	0.83	1.08	9.60	0.09	0.95	1.17	9.24	0.06	0.98	1.46
Flesh mass	7.24	0.10	0.53	0.45	13.37	0.22	3.28	16.78	10.14	0.13	3.26	20.36
Pulp mass	16.15	0.15	0.68	0.83	22.23	0.22	0.47	0.01	19.03	0.14	0.72	0.48

Figure 1a.

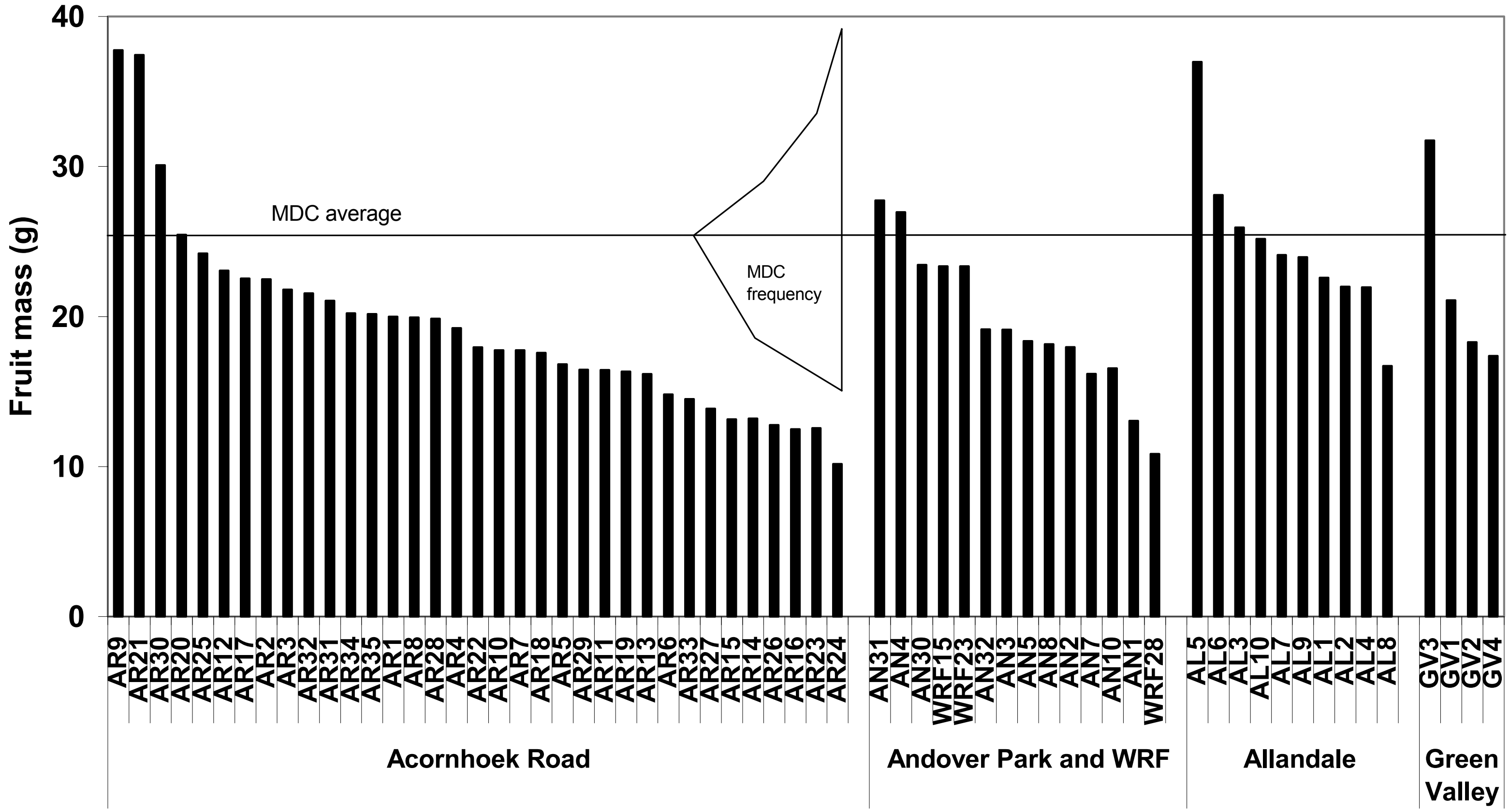
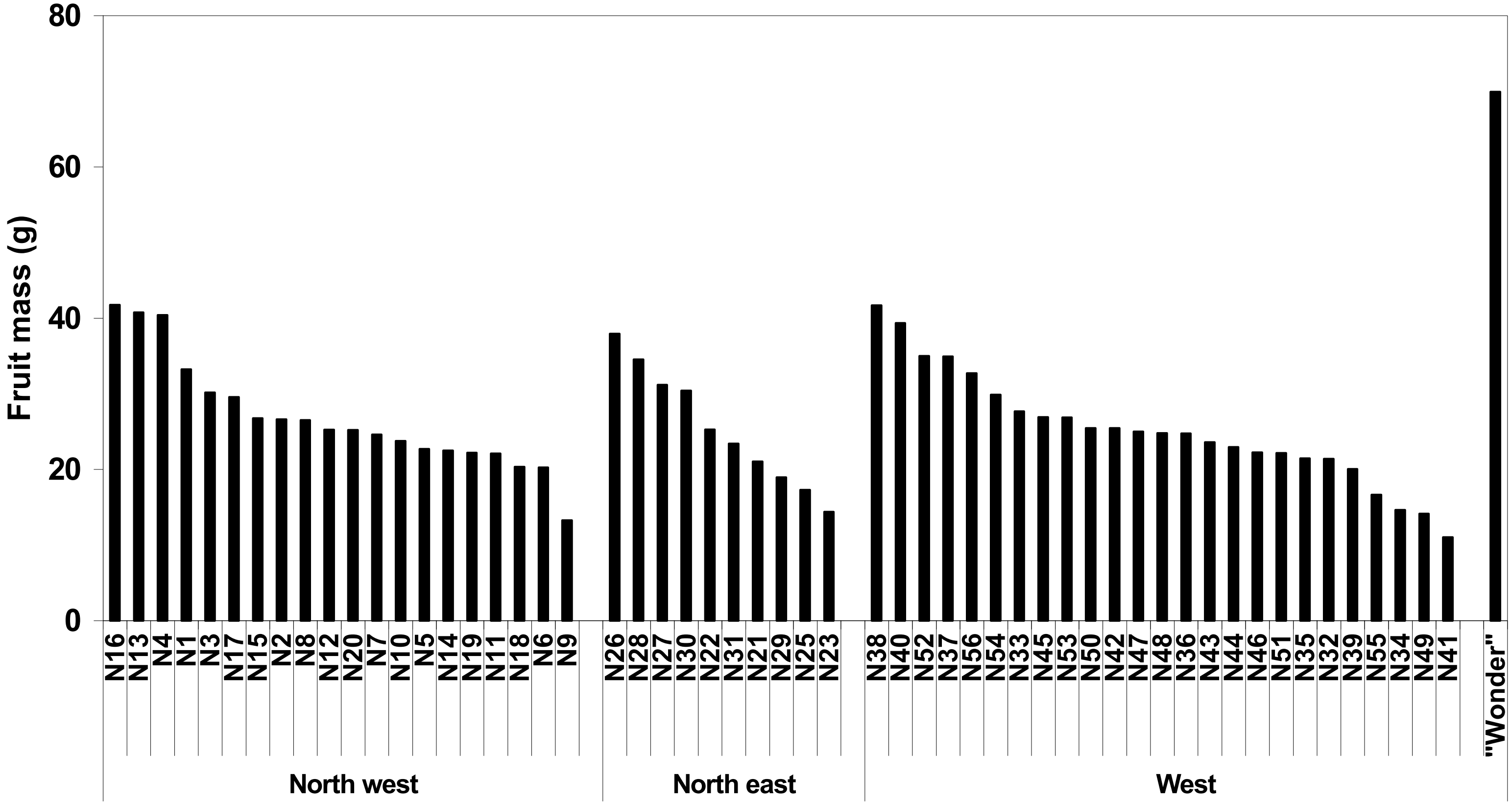

Fruit mass (g)
0
10
20
30
40
MDC average
MDC frequency
AR9
AR21
AR30
AR20
AR25
AR12
AR17
AR2
AR3
AR32
AR31
AR34
AR35
AR1
AR8
AR28
AR4
AR22
AR10
AR7
AR18
AR5
AR29
AR11
AR19
AR13
AR6
AR33
AR27
AR15
AR14
AR26
AR16
AR23
AR24
AN31
AN4
AN30
WRF15
WRF23
AN32
AN3
AN5
AN8
AN2
AN7
AN10
AN1
WRF28
AL5
AL6
AL3
AL10
AL7
AL9
AL1
AL2
AL4
AL8
GV3
GV1
GV2
GV4
Acornhoek Road
Andover Park and WRF
Allandale
Green Valley

Figure 1b.



Fruit mass (g)
80
60
40
20
0
N16
N13
N4
N1
N3
N17
N15
N2
N8
N12
N20
N7
N10
N5
N14
N19
N11
N18
N6
N9
N26
N28
N27
N30
N22
N31
N21
N29
N25
N23
N38
N40
N52
N37
N56
N54
N33
N45
N53
N50
N42
N47
N48
N36
N43
N44
N46
N51
N35
N32
N39
N55
N34
N49
N41
"Wonder"
North west
North east
West

Figure 2.

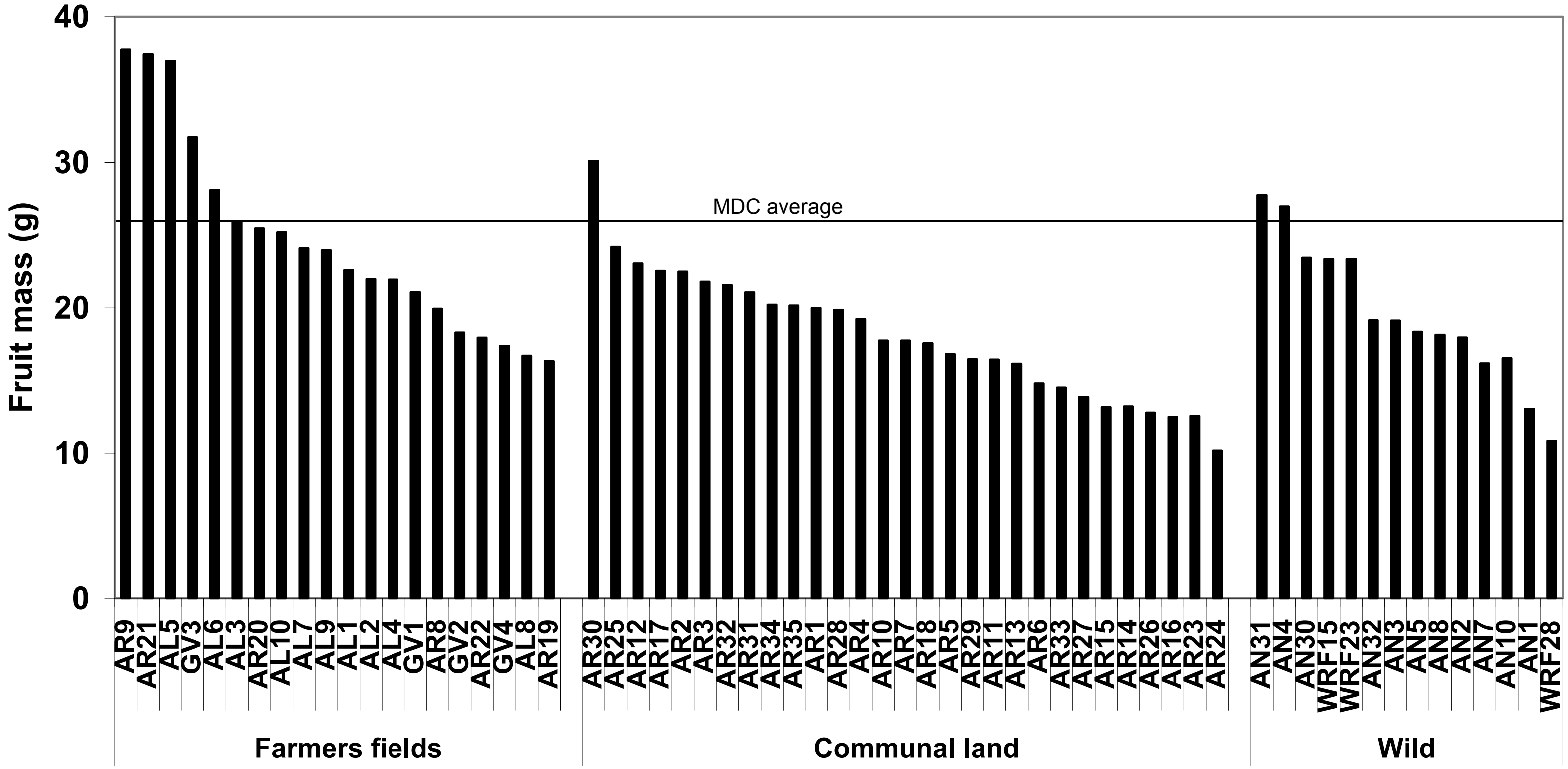

40
30
20
10
0
Fruit mass (g)
MDC average
AR9
AR21
AL5
GV3
AL6
AL3
AR20
AL10
AL7
AL9
AL1
AL2
AL4
GV1
AR8
GV2
AR22
GV4
AL8
AR19
AR30
AR25
AR12
AR17
AR2
AR3
AR32
AR31
AR34
AR35
AR1
AR28
AR4
AR10
AR7
AR18
AR5
AR29
AR11
AR13
AR6
AR33
AR27
AR15
AR14
AR26
AR16
AR23
AR24
AN31
AN4
AN30
WRF15
WRF23
AN32
AN3
AN5
AN8
AN2
AN7
AN10
AN1
WRF28
Farmers fields
Communal land
Wild

Figure 3a.

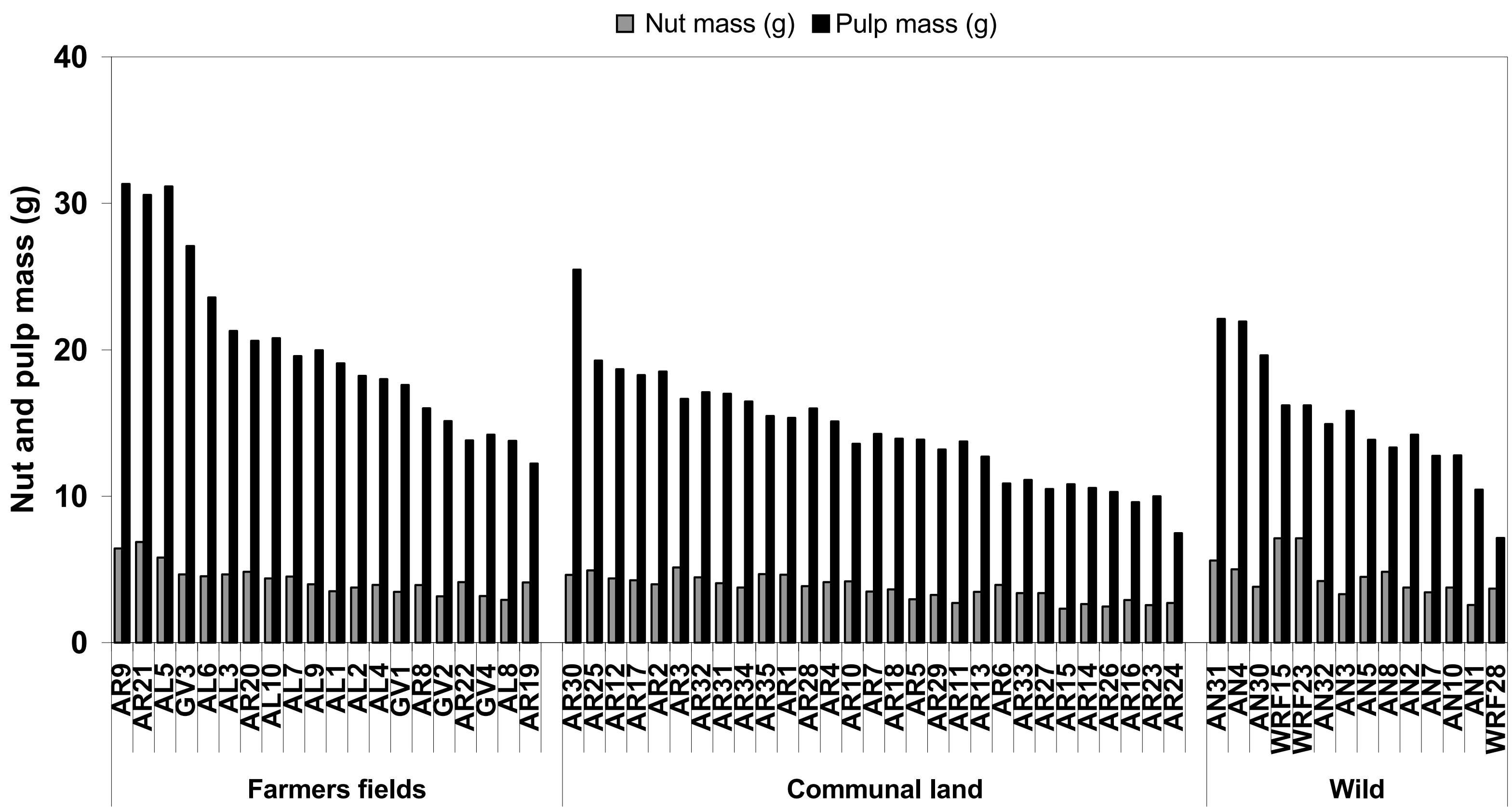

Nut mass (g)
Pulp mass (g)
Nut and pulp mass (g)
40
30
20
10
0
AR9
AR21
AL5
GV3
AL6
AL3
AR20
AL10
AL7
AL9
AL1
AL2
AL4
GV1
AR8
GV2
AR22
GV4
AL8
AR19
AR30
AR25
AR12
AR17
AR2
AR3
AR32
AR31
AR34
AR35
AR1
AR28
AR4
AR10
AR7
AR18
AR5
AR29
AR11
AR13
AR6
AR33
AR27
AR15
AR14
AR26
AR16
AR23
AR24
AN31
AN4
AN30
WRF15
WRF23
AN32
AN3
AN5
AN8
AN2
AN7
AN10
AN1
WRF28
Farmers fields
Communal land
Wild

Figure 3b.

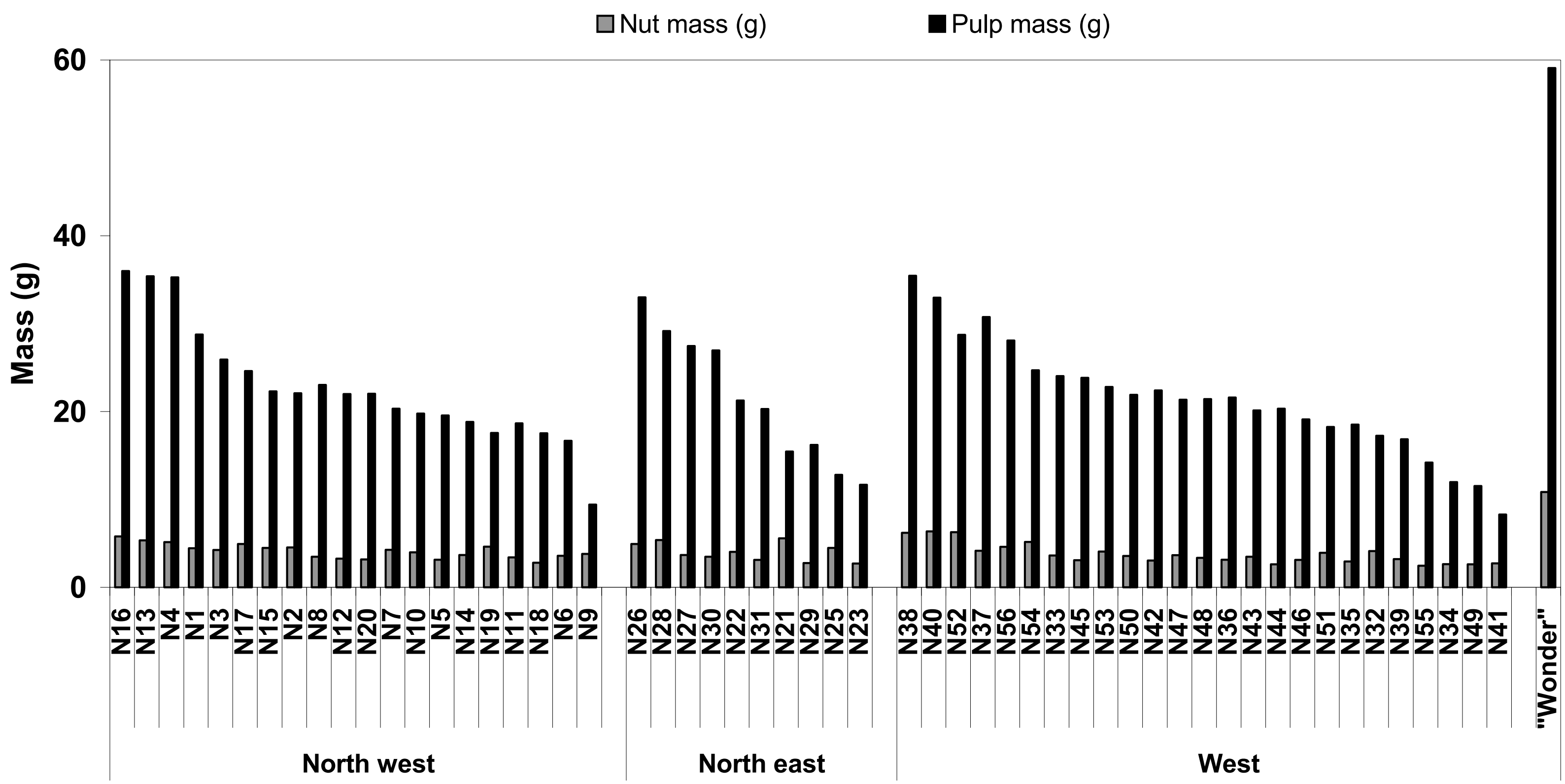

Nut mass (g)
Pulp mass (g)
60
40
20
0
Mass (g)
N16
N13
N4
N1
N3
N17
N15
N2
N8
N12
N20
N7
N10
N5
N14
N19
N11
N18
N6
N9
N26
N28
N27
N30
N22
N31
N21
N29
N25
N23
N38
N40
N52
N37
N56
N54
N33
N45
N53
N50
N42
N47
N48
N36
N43
N44
N46
N51
N35
N32
N39
N55
N34
N49
N41
"Wonder"
North west
North east
West

Figure 4a.

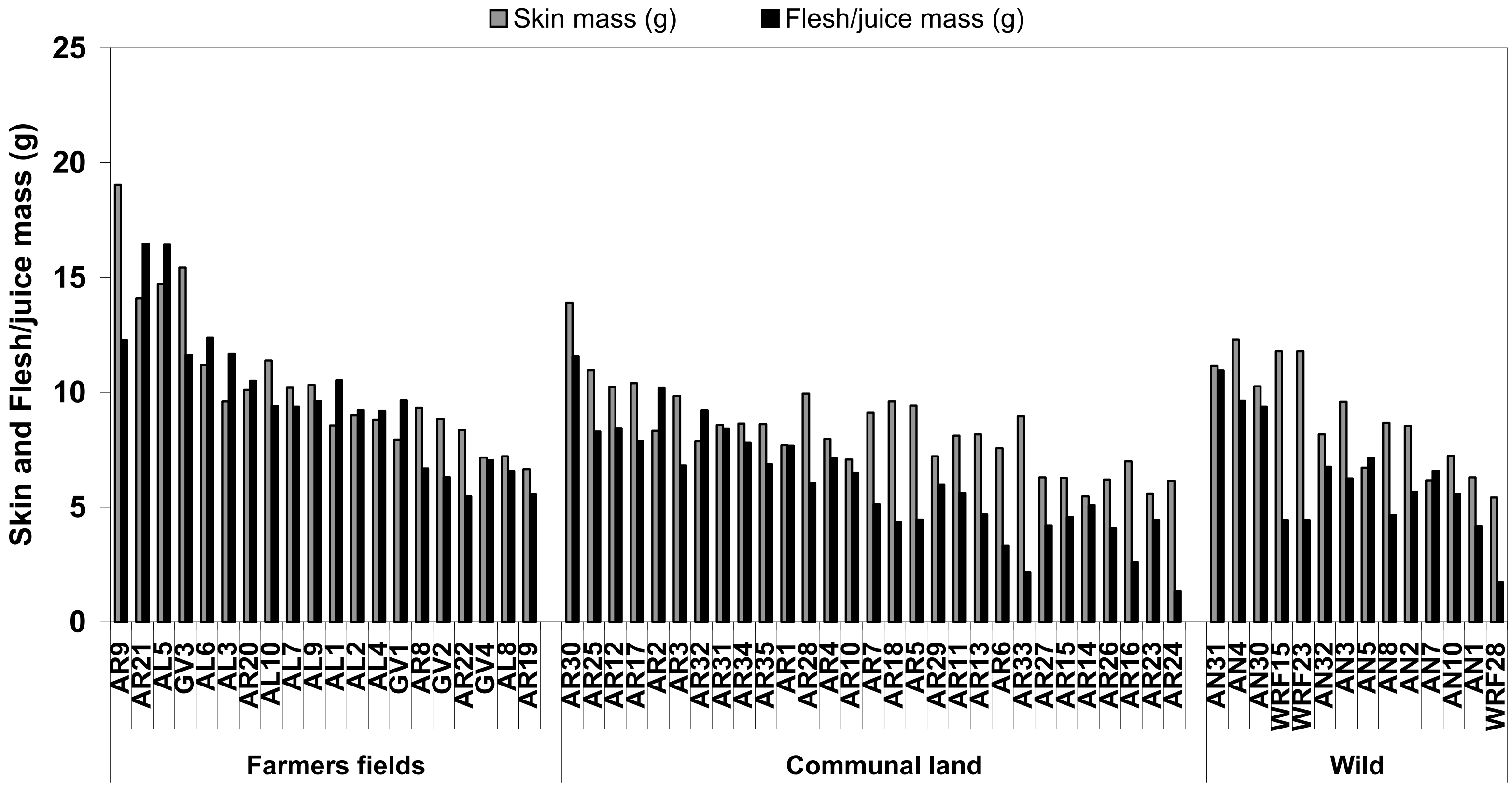
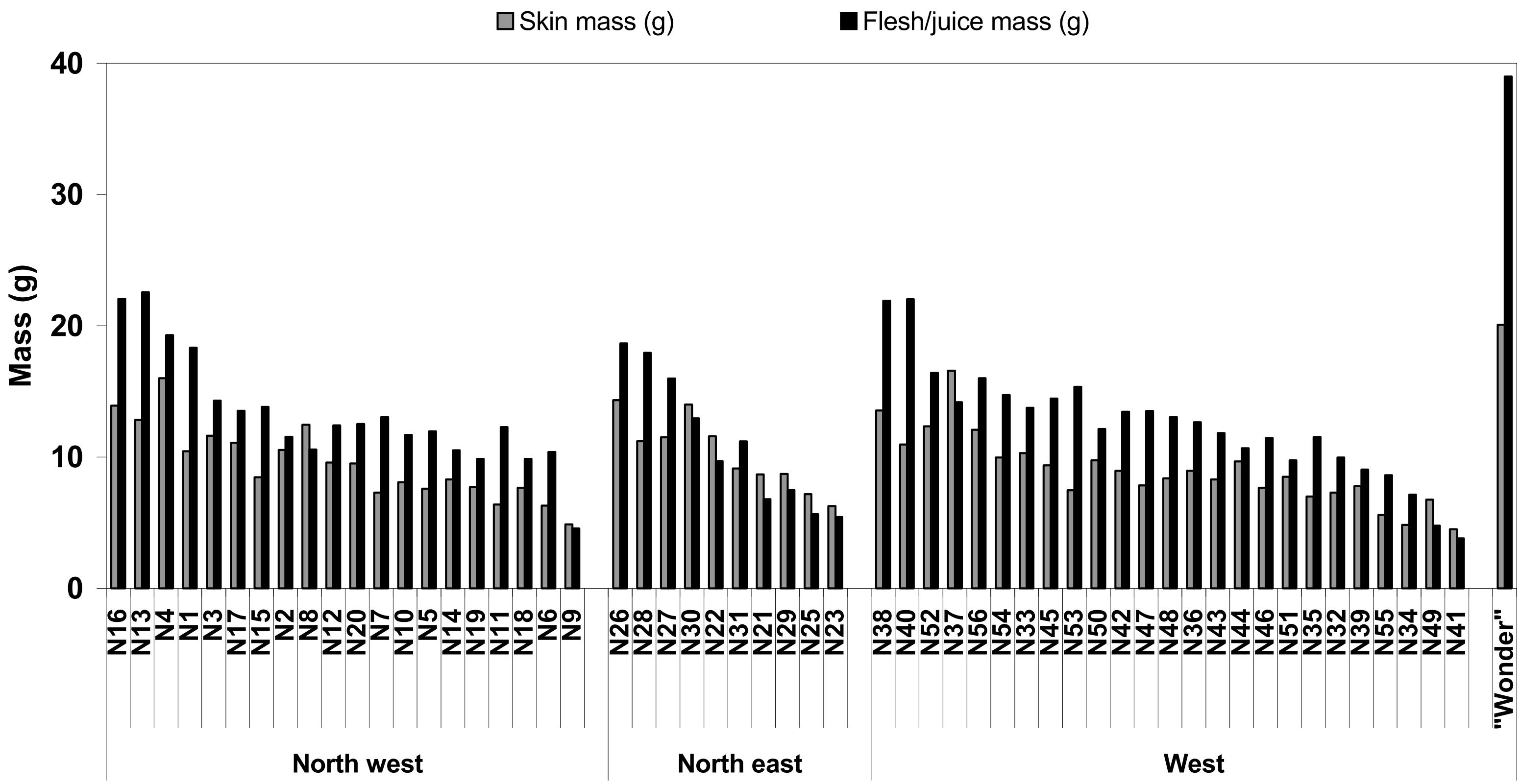

Skin mass (g)
Flesh/juice mass (g)
Skin and Flesh/juice mass (g)
25
20
15
10
5
0
AR9 AR21 AL5 GV3 AL6 AL3 AR20 AL10 AL7 AL9 AL1 AL2 AL4 GV1 AR8 GV2 AR22 GV4 AL8 AR19
AR30 AR25 AR12 AR17 AR2 AR3 AR32 AR31 AR34 AR35 AR1 AR28 AR4 AR10 AR7 AR18 AR5 AR29 AR11 AR13 AR6 AR33 AR27 AR15 AR14 AR26 AR16 AR23 AR24
AN31 AN4 AN30 WRF15 WRF23 AN32 AN3 AN5 AN8 AN2 AN7 AN10 AN1 WRF28
Farmers fields
Communal land
Wild

Figure 4b.



Skin mass (g)
Flesh/juice mass (g)
Mass (g)
40
30
20
10
0
N16
N13
N4
N1
N3
N17
N15
N2
N8
N12
N20
N7
N10
N5
N14
N19
N11
N18
N6
N9
N26
N28
N27
N30
N22
N31
N21
N29
N25
N23
N38
N40
N52
N37
N56
N54
N33
N45
N53
N50
N42
N47
N48
N36
N43
N44
N46
N51
N35
N32
N39
N55
N34
N49
N41
"Wonder"
North west
North east
West