International Scholars Journals

International Journal of Agricultural Sciences ISSN: 2167-0447 Vol. 6 (8), pp. 1100-1106, August, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Comparative analysis of inter-varietal variability in bud fertility and fruit quality of grapevine cultivars (*Vitis vinifera* L.) from Algeria

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Received 03 May 2016; Accepted 13 May, 2016 and Publish 13 August, 2016

This study was carried out at the ITAF Station at Medjez Eddchiche Region (Skikda, Algeria) in order to examine the inter-varietal differences in grapevine bud fertility and grape fruit quality, between local and introduced grapevine cultivars grown under sub-humid environment in Algeria. Eighteen grapevine cultivars were studied through the principal component analysis and the analysis of variance using the least significant difference test to achieve rankings of grapevine varieties based on their fertility and fruit quality measures. Data analysis indicate that the three introduced varieties (Cardinal, Muscat de Hambourg and Alphonse Lavallée) had significantly higher bud fertility with good fruit shape characteristics. Most studied local varieties have high sugar content. Two local varieties (Lakhdari and Bouabar Aurès) had a strong component in size and weight. We distinguish three local varieties (Muscat El Adda, Ain El Bouma and Sbaa El Tolba) significantly higher bud fertility than all other cultivars, whereas Bouabar Aurès, Lakhdari and Amokrane with good fruit quality characteristics, although they have low fertility compared to the introduced ones. These local varieties are considered good across all varieties studied and should have special attention from scientists and grapevine producers.

Keywords: Grapevine, bud fertility, fruit quality, local varieties, introduced varieties, Algeria.

INTRODUCTION

Fertility studies have been made of grapevine cultivars grown all over the world and over the time, but only a few describe those of Algeria in recent decades. In Algeria, the cultivated area of grapevines (*Vitis vinifera* L.) increased recently. According to the FAO (2015), it reached 68,564 hectares producing 570,840 tons in 2013. During the French colonization era, many new grape cultivars were introduced and cultivated in order to overcome market demand. However, the country is generally characterized by the diversity of climate conditions, mainly sub-humid in the north. Accordingly, local varieties are likely to be more resistant and more suitable for growing under local climate conditions. Their yield is sometimes low, but with higher quality. Besides, grapevine cultivars are known to vary dramatically in their fertility and berry quality characteristics (Tourky et al., 2003; Girgis et al., 2002; Fahmi et al., 2012). Thus, the introduced cultivars should be evaluated and compared by estimating their fertility and fruit quality in order to help, first, grape growers in Algeria to decide which variety will be planted, and second, policy makers to promote the adequate cultivars in terms of adaptability and productivity.

On the biological aspect of the grapevine, the latent bud

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constitutes a vegetative and reproductive potential that ensures its development in the following spring. This bud, commonly called latent eye, requires a dormancy phase in order to bud-burst (Galet, 1970). Morphologically, it is protected by scales (Bugnon and Bessis, 1968; Galet, 1970; Bouard, 1971), and has a changing size over the cycle, and a complex structure containing several buds. However, the grapevine fertility has a direct link to the study of the physiological activity of latent buds.

The purpose of this work is to highlight the inter-varietal differences in the fertility of local "autochthonous" and introduced "exogenous" *Vitis vinifera* L. varieties in Algeria. Eighteen grapevine cultivars were selected and studied through the statistical analysis of their fertility and fruit quality measures. The results allow to know better their fertility and quality. It also helps to analysis differences in fertility between local and introduced varieties. It will also allow a better use of local production and provide an analytical tool for fertility in order to adapt agricultural practices to the desired performance.

MATERIALS AND METHODS

The current study was carried out at Medjez Eddchiche Region (Skikda, Algeria), belonging to the Institute of Technical Research in Arboriculture (ITAF), in cooperation with Faculty of Biology, Constantine University.

On the used bud fertility measures

We have adopted in this study three measures developed initially by Bessis (1961). The Bessis' thesis is pioneering and notable work in the understanding of the bud grapevine fertility. This concept remain limited in simple counts of grapes number (as Laporte index of fertility and the *sortie* measure). In Bessis (1965), bud fertility measurement was treated by a more complex method. He distinguish fertility evaluated before bud-burst and that in the field. The first called real potential fertility measure, and the second, the field fertility measure. The field fertility is divided into two measures: the apparent potential fertility and the practical fertility.

The real potential fertility (RPF) expresses the average number of grapes in the all target buds before bud-burst, i.e.:

$$RPF = N_1 / x_1$$

where N_1 is the number of existing inflorescences in all latent buds (x_1). If we could actually hold grapes contained in all the buds, we should force them to bud-burst or practicing cuts in the winter (Benabedrabou, 1971). Therefore, the RPF is measured only by the methods of the anticipated fertility determination (by forcing buds or dissection). The RPF is the value expressing the average fertility of a determined bud's rank without involving the percentage of remaining latent buds. It does not sufficiently reflect the fertility status of a vineyard (Bessis, 1961). It should take into account: the richness flowering grapes and remaining latent buds (including the percentage of bud-burst). The latter involves (for Bessis) another kind of measure.

The apparent potential fertility (APF) reflects an observable potential fertility after bud-burst, assessed through effectively bursted buds. Its value expresses the ratio of the visible grapes after bud-burst on the number of shoots that carry them, i.e.:

$$APF = N_1 / x_2$$

where, N_1 always expresses the number of existing inflorescences (visible) in effectively burst buds (x_2). The value of the APF is different from that of the RPF, because it is not certain that the average for the buds that have evolved shoots be extended to those who did not developed (Benabedrabou, 1971).

Practical Fertility (PF) is represented by the ratio of total number of grapes appeared on the shoots of a bud from a given rank on the number of these buds left after the pruning, that is to say:

$$PF = N_1 / x$$

The main advantage of the PF is that the value reflects much more accurately the fertility in the vineyard (Bessis, 1965). It takes into account key variables: grapes number, grapes size and bud-burst percentage of various buds. Reynier (2011) was based, in its Manual, on the concepts of potential and practical fertility initiated by Bessis.

On the used fruit quality measures

The fruit quality measurement is about the berry weight and the length, and the grape's weight. In addition, we have used another measure in order to reflect the sugar content. Consequently, the refraction rate is employed. These measures were used largely in recent empirical studies (López-Miranda, 2004; Conde et al., 2007; Lebon et al., 2008 and Al-Obeed et al., 2010; Fawzi et al., 2015).

Study Area

This work was carried out within the *Institut Technique de l'Arboriculture Fruitière* (ITAF, Skikda, Algeria). A cultivated area of 90 hectares was operated. It contains 8 hectares devoted to vines, including 3 hectares of different table grape varieties. The field has two vineyards. One collection of local grape varieties and the other for the introduced ones.

Plant Materials

Concerning the used varieties, we used 18 grapevine varieties: for local varieties: Ahchichène, Ahmar Mechtras 3, Ahmar de Mascara, Ain El Bouma, Ain El Kelb, Amokrane, Bezoul El Khadem, Bouabar des Aurès, Ghanèz, Kabyle Aldebert, Lakhdari, Muscat El Adda and Sbaa El Tolba. For the introduced ones we used: Alphonse Lavallée, Cardinal, Dattier de Beyrouth, Italia and Muscat de Hambourg.

Experimental Protocol

In order to carry the various measures, we considered some experimental protocols for each. We will describe

them as follows. To measure the real potential fertility, we collected all six canes. This is done in late February. These canes were stored in plastic bags in a refrigerator at 4ºC for 2 months. Cuts have been achieved for each bud on the phyllotactic plan by hand under a stereoscopic microscope at a magnification of 20X. Five to seven cuts per bud were streaked on a glass slide with a drop of water and covered with a large lamella. They are then observed under a photonic microscope at 40X. The apparent potential fertility was estimated on the same ceps that were used for the real potential fertility. This was carried after bud-burst in stage G (separate grapes) of Baggiolini (1952). On the other hand, the practical fertility was estimated at the same time that the apparent potential fertility and on the same ceps. This also was conducted after bud-burst in stage G (separate grapes).

On the yield component measures, they were conducted for the weight, width and length of berries and the weight of bunches as follows. The berries were selected from ten (10) grapes from six (06) used ceps. The measures were made on 30 berries selected for each cépage. For its length and width, a calliper was used (in: Centimetre). A precision-balance was used for the berry weight (in: Gram) and grapes weight (in: Gram). In addition, the refraction rate on berry juice (in: percentage of soluble sugar) was measured by refractometer with 30 repetitions per variety.

Statistical Analysis Methods

The statistical method used is one-way analysis of variance. The method is based on the Fisher test to confirm the statistically significant difference between the distributions. It was followed by an LSD-test to identify the least significant difference in order to make the ranking. The principal component analysis (PCA) is also used to distinguish the different clusters in fertility and fruit quality measurements. We based on Protasov (2012) for the analytical approach in statistics.

RESULTS AND DISCUSSIONS

Figure 1 represents the values of fertility in the field (APF and PF) for all studied varieties. Following this representation, we can see that there are four (04) varieties having low fertility in the field (Ahchichène, Amokrane Bouabar Aurès and Kabyle Aldebert) on one side. On the other side, two (02) varieties (Alphonse Lavallée and Cardinal) represent the highest fertility values. We note that the four varieties with low fertility in the field are local varieties; the other varieties are in the range of average values of fertility including three (03) introduced varieties.

In terms of real potential fertility, Figure 2 presents its variation by variety. We note that Ahmar Mechtras III has a high fertility as a local variety placed in second rank of the most fertile varieties after Cardinal.

Besides, we performed one-way ANOVA pursued by the LSD test. The results show a significant difference in the real potential fertility between varieties at a threshold of 5% and LSD of 0.35. This culminated in a ranking 1 by the LSD test as the table 1 shows. This ranking is relatively overlapped. We can distinguish that Ahmar Mechtras III leads the class as the local variety with the highest level RPF, followed by three introduced varieties (Cardinal, Muscat de Hambourg and Alphonse Lavallée). It may take five (05) last varieties as a whole class with low RPF. It contains only local varieties.

For the apparent potential fertility, the ANOVA showed a significant difference at 5% with an LSD of 0.30 (Table 1, ranking 2). The second ranking places two varieties introduced to a first class (Alphonse Lavallée and Cardinal). The first local variety with significant APF is Sbaa El Tolba in fourth place. The last half of this ranking includes only local varieties.

Concerning the practical fertility, the results also showed a significant difference at 5% with 0.316 LSD (Table 1, ranking 3). The first class includes three introduced varieties (Cardinal, Alphonse Lavallée and Muscat Hamburg), followed by El Sbaa Tolba and El Muscat Adda placed the first in the next class. It is found that half of the studied varieties with low PF contains only local grapevines. This, in relation with the previous two rankings could be generalized by noting that half the studied varieties with low fertility are local varieties.

Based on the total data, which represents the aggregate experimental matrix including all measurements, we use a principal component analysis (PCA). The results show the two components with 67.14% participation in the total inertia. The first component contributes about 38.36%, and the second at 28.77%. The figure 3 traces of the factorial coordinates of the variables by a correlation circle based on our global matrix, where the variables are represented by their projection on the plane of the first two components.

Based on the angle of the plotted variables, we can make out three major variations. The first block of fertility measurement variables (RPF, APF, PF and Bud-burst rate). The second represents the four variables of the yield components. The third one is about the refraction.

Figure 4 shows the result of principal component analysis. It sets the horizontal axis by the first principal component (F1) containing essentially the three fertility measures and weight of the berries. The vertical axis represents the second principal component (F2) containing essentially the four yield component variables. In terms of the first principal component, this representation has made a clear distinction between introduced and local varieties. The first block includes the introduced varieties in the first place, being a block containing five (05) introduced varieties with high participation in inertia, that is to say that the introduced varieties have high levels in both three fertility measures and yield components.

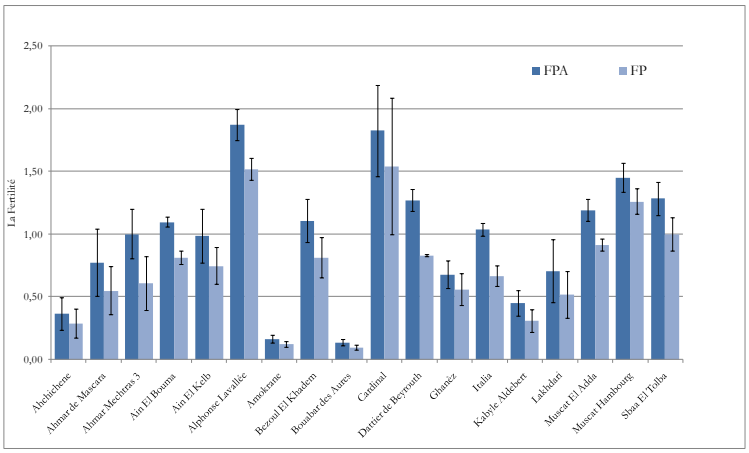

Figure 1. Fertility in the field (potential apparent fertility and practical fertility) by variety.

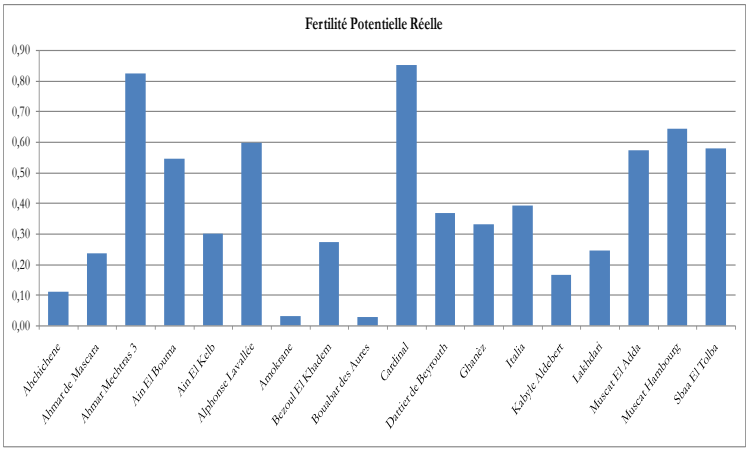

Figure 2. The actual potential fertility according to variety.

All local grapevine varieties have a small share in the first principal component. They form a whole block (values below 1) starting with Muscat El Adda, going left to the lower value in this component. In terms of the second principal component, reflecting primarily the four measures of the fruit quality (length, width and weight of berry and grape weight), we distinguish six (06) varieties with high participation. They include the essentially hypersized varieties, that is to say that these varieties have high values in terms of the shape characteristics.

Taken together, the two components showed four varietal categories. A first category includes three introduced varieties (Alphonse Lavallée, Dattier Beyrouth, and Italia). It is characterized by a high participation in the two principal components, i.e., a hypersized shape with significant levels of fertility. In contrast, a category that weakly involved in both components (Kabyle Aldebert, Ahchichène, Bezoul El Khadem, Ain El Bouma, Ain El Kelb, Ahmar Mechtras III, and Sbaa El Tolba), it is characterized by low fertility with reduced fruit shape characteristics. On the other hand, we see two opposing categories. One of them has a strong participation in the second component and low in the first. It includes three local varieties (Bouabar Aurès, Amokrane, and Lakhdari). They have substantial size with low fertility. The last category includes the varieties with strong participation in the first component and low in the second. It also includes three varieties (Cardinal, Muscat Hamburg, and Muscat El Adda). It is characterized by the most fertile varieties with reduced fruit shape characteristics.

In terms of fertility, we perform another PCA for only the fertility measures. We get a main axis component (F1) representing both the practical fertility and the apparent potential fertility, and an axis of the main component (F2) representing bud-burst rate. Figure 5 shows the graph of the CPA those results. The first axis of fertility (horizontal) indicates the most fertile varieties (on the right) to the less fertile varieties on the left. We can conclude the existence of two categories of fertile varieties.

Table 1. Results of the grapevine varieties ranking by the RPF, APF and PF based on LSD-test

RANKING 1			RANKING 2			RANKING 3		
Class	Cépages	T Group	Class	Cépages	T Group	Class	Cépages	T Group
[1]	Ahmar Mechtras III	A	[1]	Alphonse Lavallée	A	[1]	Cardinal	A
[2]	Cardinal	AB	[2]	Cardinal	A	[2]	Alphonse Lavallée	A
[3]	Muscat de Hambourg	ABC	[3]	Muscat de Hambourg	B	[3]	Muscat de Hambourg	AB
[4]	Alphonse Lavallée	ABC	[4]	Sbaa El Tolba	BC	[4]	Sbaa El Tolba	BC
[5]	Muscat El Adda	ABCD	[5]	Dattier de Beyrouth	BC	[5]	Muscat El Adda	CD
[6]	Ain El Bouma	ABCD	[6]	Muscat El Adda	BC	[6]	Dattier de Beyrouth	CDE
[7]	Sbaa El Tolba	ABCD	[7]	Bezoul El Khadem	C	[7]	Ain El Bouma	CDE
[8]	Italia	BCDE	[8]	Ain El Bouma	C	[8]	Bezoul El Khadem	CDE
[9]	Dattier de Beyrouth	CDEF	[9]	Italia	CD	[9]	Ain El Kelb	CDE
[10]	Ghanèz	CDEF	[10]	Ahmar Mechtras III	CDE	[10]	Italia	DE
[11]	Ain El Kelb	CDEF	[11]	Ain El Kelb	CDE	[11]	Ahmar Mechtras III	DEF
[12]	Lakhdari	DEF	[12]	Ahmar de Mascara	DEF	[12]	Ghanèz	EFG
[13]	Ahmar de Mascara	DEF	[13]	Lakhdari	EFG	[13]	Ahmar de Mascara	EFG
[14]	Kabyle Aldebert	EF	[14]	Ghanèz	FG	[14]	Lakhdari	EFG
[15]	Bezoul El Khadem	EF	[15]	Kabyle Aldebert	GH	[15]	Kabyle Aldebert	FGH
[16]	Ahchichène	EF	[16]	Ahchichène	HI	[16]	Ahchichène	GH
[17]	Amokrane	F	[17]	Amokrane	HI	[17]	Amokrane	H
[18]	Bouabar des Aurès	F	[18]	Bouabar des Aurès	I	[18]	Bouabar des Aurès	H

On the one hand, the results show two categories. One category containing three introduced varieties with rela tively strong contribution in the second component (bud-burst rate). It includes Muscat Hamburg, Alphonse Lavallée, and Cardinal. On the other hand, the second category of the most fertile varieties contains three local varieties.

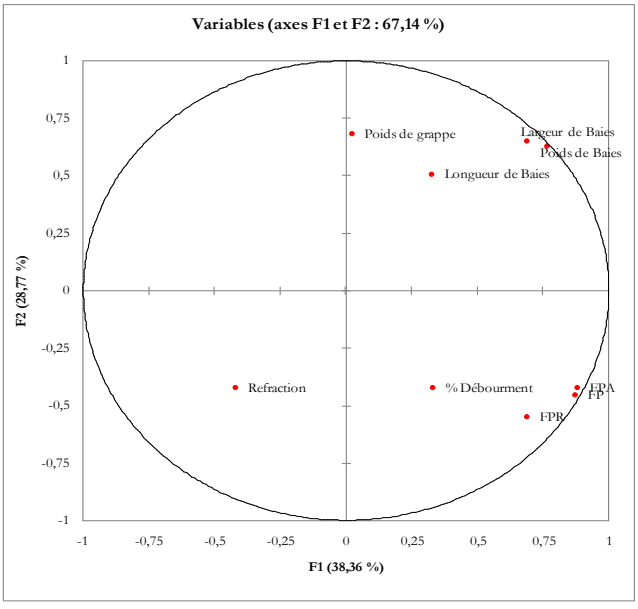

Figure 3. Plot of factorial coordinates of the variables.

It includes Sbaa El Tolba, Muscat Adda and Ain El Bouma those who are qualified as the varieties with a strong contribution in the first component. In terms of the second component, reflecting the bud-burst rate, it is noteworthy that most varieties have a high bud-burst rate are local varieties with the exception of the first category of three most fertile introduced varieties (over the first component).

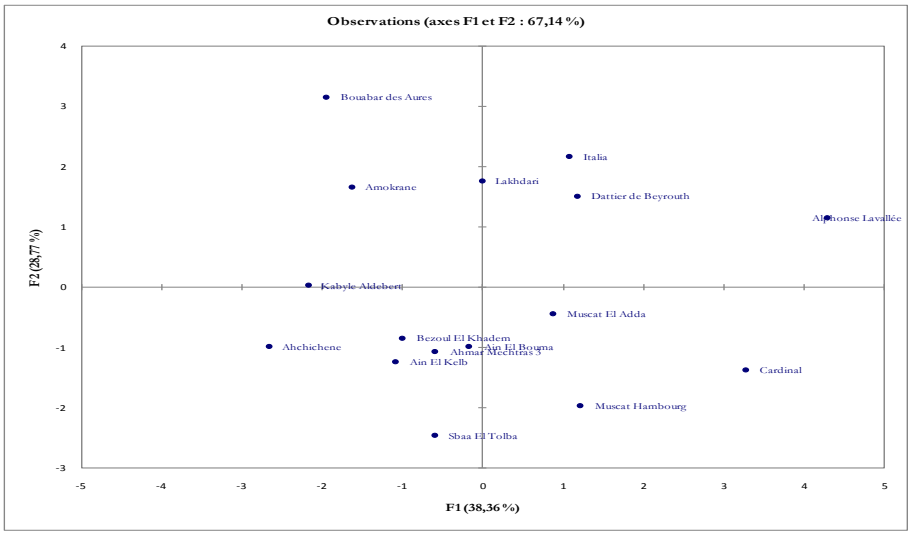

Figure 4. PCA for all varieties on the base of fertility measures and fruit quality.

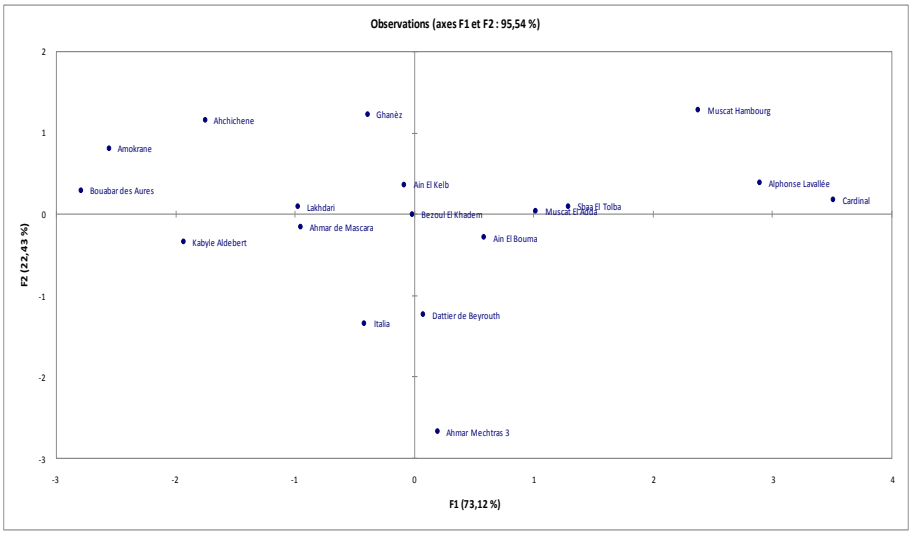

Figure 5. PCA for all varieties on the base of fertility measures.

CONCLUSION

This study contributes a precise examination of the inter-varietal differences in bud grapevine fertility and fruit quality between local and introduced grapevine cultivars under field conditions in Algeria. For this, we opted for an experimental comparative study of bud fertility of grapevine (*Vitis vinifera* L.). We have been able to capture some bud fertility measures for 18 Algerian varieties. The data has parlayed several interesting findings summarized as follows. Most studied local varieties have a high sugar content inferred by the high refraction rate. Two local varieties (Lakhdari and Bouabar Aurès) have a strong component in size and weight. The three local varieties (Muscat El Adda, Ain El Bouma and Sbaa El Tolba) have relatively high fertility

compared with the studied varieties. The three introduced varieties are grabbing all levels of measures. They are the most fertile with good fruit shape characteristics. Those are Cardinal, Muscat de Hambourg and Alphonse Lavallée. We distinguished three local varieties (Bouabar Aurès, Lakhdari, and Amokrane) having good fruit shape characteristics although they have low fertility compared to the introduced ones. The concluded local varieties considered as good across all varieties studied should have special attention from scientists and grapevine producers.

ACKNOWLEDGEMENTS

This work was supported by grants provided by The Institute of Technical Research in Arboriculture (ITAF) and Department of Plant Ecology and Biology, Constantine University. We thank the staff of the ITAF Institute for their useful help.

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