Agro-morphological and sensory characterization of cocoyam (*Xanthosoma sagittifolium* (L) (Schott) germplasm in Ghana

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ABSTRACT

Seventy-eight accessions of cocoyam (*Xanthosoma sagittifolium* (L.) Schott) were collected from seven regions of Ghana to gather the available germplasm for conservation and use. The materials were planted at the Plant Genetic Resources Centre (PGRC), Bunso and characterized agro-morphologically using the International Plant Genetic Resources Institute's (IPGRI) descriptors for *Xanthosoma*. Twenty-one qualitative and 10 quantitative characters were studied. Two main groups were identified based on characters of the pseudo-stem and colouration of the apical portions of cormels. However, three groups were identified based on cooked cormel qualities. The qualitative character which recorded the highest polymorphism was the cooking quality of cormels with a diversity index of 0.540. A cluster analysis using the 31 characters showed eight distinct groupings. A further characterization using molecular methods is recommended to indicate more variability or otherwise in the germplasm.

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RÉSUMÉ

OPOKU-AGYEMAN, M. O., BENNETT-LARTEY, S. O. & MARKWEI, C.: *Caractérisation agro-morphologique et sensorielle du germeplasme de taro* (Xanthosoma sagittifolium *(L.) Schott) au Ghana.* Soixante-dix-huit accessions de taro *(Xanthosoma sagittifolium* (L.) Schott) étaient ramassées de sept régions du Ghana pour rassembler les germeplasmes disponibles pour conservation et utilisation. Les matèriels étaient plantés au Centre de Resources Génétique de Plante (CRGP) à Bunso et caractérisés agro-morphologiques utilisant les descripteurs de l'Institut International de Resources Génétique de Plante (IIRGP) pour *Xanthosoma.* Vingt-un caractères qualitatifs et neuf quantitatifs étaient étudiés. Deux groupes majeurs étaient découverts basés sur les caractères de pseudo-tige et la coloration des parties apicales des cormels. Toutefois, trois groupes étaient découverts basés sur les qualités de cormels cuites. Le caractère qualitatif donnant le plus élevé de polymorphisme était la qualité de cuisson de cormels avec l'indice de diversité de 0.540. Une analyse groupée utilisant 31 caractères révélait huit regroupements distincts. Une caractérisation supplémentaire utilisant les méthodes moléculaires est recommandée pour révéler plus de variabilité ou autrement dans le germeplasme.

Introduction

Cocoyam (*Xanthosoma sagittifolium* (L.) Schott) is a vegetatively propagated monocot tuber of the family *Araceae* (Purseglove, 1972). It is a staple crop in West and Central Africa, grown mainly in Cameroon, Gabon, and Ghana. The starchy cormels and tender leaves, consumed in various ways, are excellent sources of carbohydrates, minerals, and vitamins. They also serve as a source of income for many families in the tropics and subtropics (Tambong *et al.*, 1997). The cormels are eaten boiled, baked, fried, or roasted. Cocoyam is also eaten as 'fufu', a West African dish prepared by pounding boiled tubers in a wooden mortar into a paste. Sometimes flour is prepared from cocoyam and the leaves are also incorporated into poultry feed.

Cocoyam grows well in shade, which facilitates its intercrop with permanent plantations of banana, coconut, citrus, oil palms, and cocoa. It is also intercropped with annual and perennial crops; thus, making it a choice crop in the farming systems of the forest and forest/savanna transition zones of Ghana. The crop is well known for its profuse sprouting as a volunteer crop after the clearing and burning of secondary forests. For large-scale farmers, scarcity of planting material is a real problem. Most farmers take advantage of volunteer plants, known by some Akan tribes in Ghana as 'Ogya mo', meaning, 'well done fire', because they believed that the burning of the bush caused the cocoyam to sprout.

Cocoyam produces the best yields in well-drained fertile loamy soils with abundance of organic matter. The persistent decline in soil fertility, together with the loss of forest, are accelerating the decline in the diversity of the crop, which is already known to have a very narrow genetic base as an introduced crop in West Africa (Wright, 1930).

Ene (1987) enumerated some problems associated with the production of cocoyam such as the root-rot disease, low yield, poor shelf life, and suitability for target products.

Tambong *et al.* (1997) have reported that some cocoyam germplasm thought to have root-rot resistance potentials were collected in Ghana for research in the Cameroon. The same authors have, however, lamented the loss of all the germplasm that was collected. It would be important to know what is left of cocoyam diversity in the field within Ghana, since this germplasm still remains the only hope for improving the crop.

Cocoyam diversity has not been extensively researched in Ghana. The main objective of this work was to characterize the cocoyam germplasm collection at Bunso, Ghana, using agro-morphological and sensory descriptors to identify and document the available diversity; to eliminate unintended duplications for efficient conservation and use; and to take appropriate plant genetic resources management decisions.

Materials and methods

Seventy-eight accessions of cocoyam (*Xanthosoma sagittifolium* L. Schott) germplasm collected in 1993, 1996/1997, and 1998 by different collecting missions from six cocoyam-growing regions of Ghana, namely the Ashanti, Brong Ahafo, Central, Eastern, Volta, and Western Regions and were planted in 1999 and 2000 for characterization. The germplasm is conserved in a field gene bank at the PGRC at Bunso, which has a moist semi-deciduous forest ecology. The soil in the field for the study is sandy clay loam classified as Eutric Cambisol, and referred to locally as Birim (Senayah, Asiedu & Tetteh, 1997). The field had been previously cultivated with yam (*Dioscorea* spp.), followed by mucuna (*Mucuna pruriens* DC var. *utilis* Wall).

A surface dressing of poultry manure at the rate of 2.5 t ha^{-1} was broadcast on all the plots before planting. Cocoyam corms ranging between 300 and 400 g were planted in a randomised complete block design. Twelve stands of each accession were planted using a distance of 1m × 1m between and within rows in each of three blocks.

Thirty-one characters were studied. Except otherwise stated, all characters were studied using the IPGRI descriptors for *Xanthosoma* (IBPGR, 1989), and colour-related descriptors were characterized using colour charts from the Methuen Handbook of Colours (Kornerup & Wanscher, 1978).

List of characters studied

The characters studied comprised the following:

1. Leaf surface glossiness
2. Leaf surface glaucous
3. Colour of upper leaf surface
4. Colour of lower leaf surface
5. Midrib and leaf veins in cross section
6. Cross section of petiole sheath
7. Petiole colour upper two-thirds
8. Petiole attachment
9. Lamina orientation

10. Leaf margin (undulation)
11. Leaf margin colour
12. Petiole colour lower one-third
13. Petiole surface glaucous
14. Edge colour of petiole sheath
15. Shape of cormels
16. Cooked cormel quality
17. Corm shape
18. External colour of cormel
19. Flesh colour of cormel
20. Exterior surface of cormel
21. Colour of cormel apex
22. Petiole sheath length
23. Petiole length
24. Plant height
25. Lamina length
26. Lamina width
27. Corm circumference
28. Corm height
29. Number of corms per stand
30. Number of secondary axillary buds
31. Cormel fresh weight

Determination of quantitative traits

Lamina length and width. Five plants per row were selected at random and tagged for data collection. Three fully expanded leaves were randomly selected for the measurements. Lamina length was measured at the longest points on the lamina along the midrib. Lamina width was measured at the widest points of the lamina, perpendicular to the midrib. The measurements were taken at 6 months after planting when the plant would have reached its peak above ground vegetative growth.

Cormel fresh weight and number of cormels per stand. The data were collected from five stands per accession at 11 months' maturity. The tubers were weighed and counted in each accession.

Cormel size at maturity. The tubers harvested at 11 months after planting were grouped by weight into the following classes:

Small ≤ 200 g
Medium > 200 g < 400 g
Large ≥ 400 g

Above-ground corm circumference. The circumference of the corm portion immediately above the ground was measured just before harvesting; first with a string, and then a measuring tape was used to record the actual readings. All corms were measured, and mean values were recorded for stands with more than one corn.

Determination of qualitative traits

Exterior surface colour of cormels. All cormels from the same accession were bulked and 10 samples selected at random. The colouration of the exterior surface was determined after washing off sand particles on the cormels and leaving them air-dried. Cormels from the same sample were also cut in longitudinal sections, and colour chart was used to determine the cormel 'flesh' colour (Kornerup & Wanscher, 1978).

Cooking quality. Cooking quality was assessed through a subjective analysis, using a 7-member panel. The cormels were peeled and cut into 40 g (± 5 g) slices. They were kept in labelled transparent polythene bags and boiled for 10 min. This test was repeated three times– immediately after harvest, 3 weeks after harvest, and 6 weeks after harvest. The boiled cocoyam was scored on a scale of 1-5 (1= very soft and 5= very hard). It was rated as soft if sample was soggy to the touch or when pressed with the fingers, and hard if sample was hard to the touch and floury when broken using one's fingers.

Diversity indices were calculated for the qualitative characters that showed polymorphism in the various traits, using a formula by Shannon & Weaver (1963), following Galwey (1995) and Bisht, Mahajan & Patel (1998) as follows:

$$SDI_i = -\sum_{j=1}^{d_i} p_{ij} \log p_{ij}$$

where SDI = Shannon's Diversity Index for the i^{th} qualitative character; d_i being the character state for i^{th} character, and p_{ij} the proportion of accessions for j^{th} character state of i^{th} character.

Some descriptive statistical parameters were computed for the quantitative characters. An average group linkage cluster analysis, using data on all characters studied, was applied. A dendrogram was drawn and the analysis was based on the 50 per cent similarity coefficient as the cut-off point on the dendrogram. A 'quick cluster' analysis for plant size-related quantitative data were also undertaken.

Results and discussion

Eight of the qualitative characters accessed did not show polymorphism among the accessions. Fifteen other qualitative characters, however, had variations that ranged from two to four categories for the various characters (Table 1). The character with the highest diversity was the cooking quality with diversity index of 0.540. It was followed by the colour of upper leaf surface and shape of cormels with diversity indices of 0.497 and 0.495, respectively. The cross section of petiole sheath had the lowest diversity index of 0.118. Table 1 shows the percent frequencies of various categories of characters and their diversity indices within the total germplasm.

The relatively high diversity in cooking quality or texture of boiled cocoyam cormels corroborates the findings of Markwei, Bennett-Lartey & Quarcoo (2000) in an ethnobotanical study on cocoyam. It was observed that cooking quality is one of the major characters that local farmers use to distinguish between cocoyam varieties, especially when all other visible characters fail to distinguish between them. The white-fleshed cocoyams for instance, are often referred to either

TABLE 1

Frequency Distribution and Shannon's Diversity Indices (SDI) in Qualitative Characters of Cocoyam Germplasm that Showed Polymorphism

Character	*Category*	*% frequency*	*SDI**
Leaf surface glossiness	Present	61.5	0.130
	Absent	38.5	0.160 (0.290)
Leaf surface glaucous	Present in upper surface	23.1	0.147
	Present in both surfaces	3.8	0.054
	Absent in both surfaces	73.1	0.090 (0.291)
Colour of upper leaf surface	Light-green	7.7	0.086
	Medium-green	42.3	0.158
	Green	9.0	0.094
	Dark-green	41.0	0.159 (0.497)
Colour of lower leaf surface	Light-green	30.8	0.158
	Medium-green	64.1	0.124
	Green	5.1	0.066 (0.348)
Leaf margin colour	Clearer	3.8	0.054
	Red/purple	88.5	0.047
	Concolourous	3.8	0.054
	Creamy	3.8	0.054 (0.209)
Petiole colour lower third	Light-green	2.6	0.041
	Green	39.7	0.159
	Dark-green	2.6	0.041
	Green streaked with purple/red	55.1	0.143 (0.384)
Cross section of petiole sheath	Straight	92.3	0.032
	Curved out	7.7	0.086 (0.118)

Petiole sheath edge colour	Pink/red	53.6	0.127
	Clearer than rest of petiole sheath	23.4	0.147
	Darker than rest of petiole sheath	9.1	0.095
	Same colour as petiole and sheath	3.9	0.055 (0.424)
Shape of cormels	Ovate	48.1	0.154
	Elliptical	35.1	0.160
	Cylindrical	7.8	0.086
	Globose	9.1	0.095 (0.495)
Cormel size at maturity	Small	11.7	0.108
	Medium	45.5	0.156
	Large	42.9	0.046 (0.310)
Cooking quality	Very soft	14.1	0.120
	Soft	10.3	0.102
	Medium	41.0	0.159
	Hard	34.6	0.159 (0.540)
External surface colour of cormels	Light-brown	76.6	0.089
	Brown	2.6	0.041
	Dark-brown	20.8	0.142 (0.272)
Internal colour of cormels	White	28.6	0.155
	Whitish-purple	63.6	0.125
	Pinkish	5.2	0.067
	Pale-red	2.6	0.041 (0.388)
Exterior surface of cormel	Smooth	76.9	0.088
	Fibrous	23.1	0.143 (0.231)
Colour of cormel apex	White	19.5	0.138
	Pink/red	80.5	0.079 (0.217)

* Figures in parenthesis are the Shannon's Diversity Indices for the entire character.

as soft or hard white, by virtue of their cooked consistency.

Eight groups were identified in a cluster analysis using 31 characters. The important characters for the formation of these clusters were cormel flesh colour (red and white cocoyam), cooking quality (soft and hard texture of boiled cormels), and plant size (dwarf and tall). Unexpected clusters were also formed by characters that did not point to the already known genotypes. Groups of white and red types were brought into a cluster on account of plant height, cormel shape, texture of exterior surface of cormel, and colour of leaf margin. Similarly, unexpected groupings were found by Schnell, Goenaga & Olano (1999) in variability studies in cocoyam using Random Amplified Polymorphic DNA (RAPD).

The eight-cluster groups contained 10, 15, 9, 28, 1, 6, 5 and 2 accessions, respectively. The largest cluster made up of 28 accessions was the most unexpected group (made up of different morpho-types). The strongest linkage character in the group was the red or pink cormel apex. Twenty-five out of the 28 accessions had the pink or red cormel apex, which was also the trait of the hard-boiled cormels. Two accessions, SCJ98002 and RAX93005 within the group, however, had white cormel apex in the same group (Fig. 1).

The smallest cluster with one accession (BD96179), which stood separated from the other groups (Fig. 1), had a white cormel flesh with a rather fibrous tuber skin as compared to the larger group with mostly whitish purple cormel flesh and smoother cormel skin. This accession requires special care due to the few representatives it has within the collection, to safeguard it from extinc-

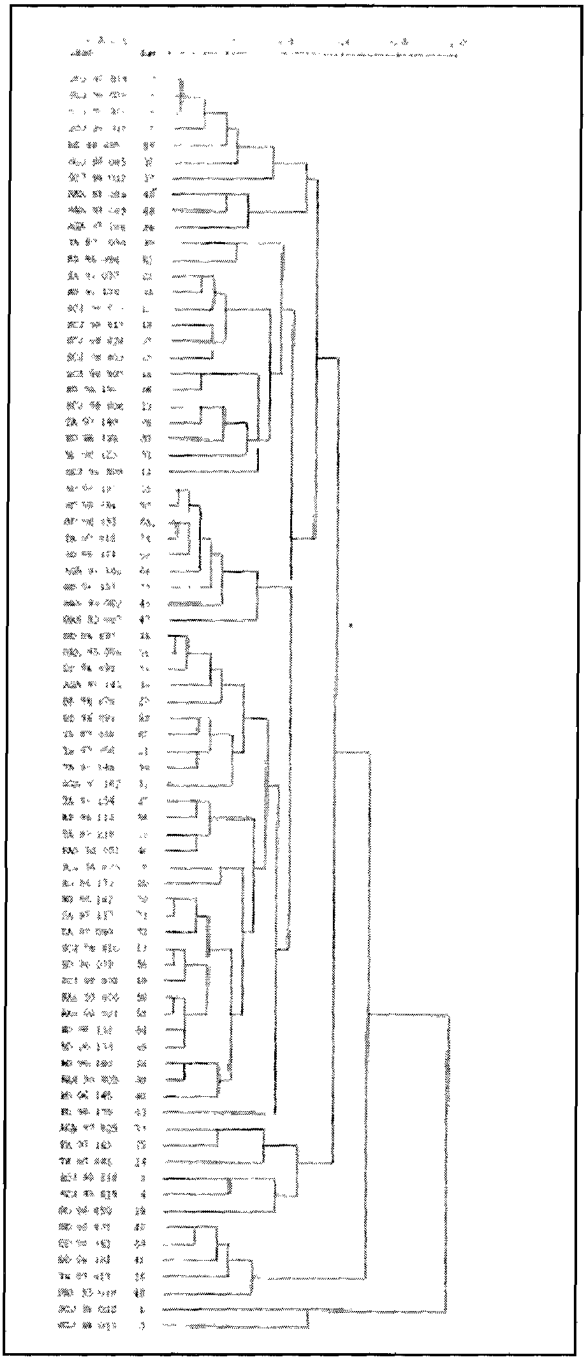

Fig. 1. Dendrogram using Average Linkage (Between Groups) obtained from 31 characters of cocoyam germplasm.

tion.

Another group that requires special care is the cluster with two accessions, SCJ98022 and SCJ98013. They were all white types with white cormel apex and a curved out lower petiole sheath, which was found to be a mark of very soft-boiled cormel, and are probably very early maturing types (flowering at 4 months after sprouting).

From recent available ethnobotanical information, the three genotypes of cocoyam that are known are red, hard-white, and soft-white. This characterisation uses colour of cormel apex and tuber flesh to differentiate the reds from the whites. Two different varieties that are also found within the white types are also differentiated by the texture of the boiled cormel (Markwei *et al.*, 2000), which the authors have termed cooking quality in this study. The hard-white has a vegetative appearance just as the red type. It is only when harvested that one who is not familiar with the cultivars could differentiate one from another.

Wright (1930) and Doku (1966) found four cultivars of cocoyam in Ghana. Two of them were 'Amankani kokoo' which had pink/red cormels, and 'Amankani fufu' which means white cocoyam. The latter type, according to Doku (1966), had the same leaf and petiole colours as 'Amankani kokoo', but had white cormels. The third type was 'Amankani fitaa' which also means white cocoyam and looked just like the 'Amankani fufu' in all aspects, except for the absence of constrictions on the cormels. The fourth type was known as 'Amankani antwibo', which was not included in this study.

Based on the foregoing, it is clear that Wright (1930) did not include the genotype 'soft-white' as is found in the current collection under study, since this material is entirely different in vegetative outlook. The 'soft-white' cocoyam may either be a recent introduction to Ghana or Wright's (1930) survey might have been unable to capture this material at the time of his study. The constricted white type referred to by Wright (1930) has also not been found in the current collection, which may be due to either the current collecting expedition's inability to capture it, or it is extinct from Ghana. The only major cormel skin 'deformity' observed was rough spots in the form of buds on the skin of the 'soft-white' types. The difference between the two categories of the 'soft-white' was that one was harder and had fewer rough spots on the skin.

Tambong *et al.* (1997) observed three groups of cocoyam germplasm collected from several countries including Ghana as white, pink and yellow flesh tubers. The yellow flesh type has not been found in any of the recent collecting missions, which indicates its extreme scarcity or probable extinction in Ghana.

All differences in the cocoyam germplasm have so far been based on qualitative characters. However, field observation during this study showed certain variability based on metric traits that were so glaring as to be assummed as being influenced by genetic factors. Table 2 shows some descriptive statistics of some quantitative characters of cocoyam germplasm at Bunso.

The characters petiole sheath length, petiole length, lamina length, lamina width, and overall plant height had direct correlation with the plant size (tall and short, giant and dwarf, etc). These characters were analysed using a 'quick cluster' method. Five clusters were used. The groups in the two extremes (Clusters 2 and 3) were labelled as the giants and dwarfs, respectively (Table 3). The accessions that fell within the median group (Cluster 5) were labelled as the medium types. The other two linking groups (Clusters 1 and 4) were not classified, but could, however, be linked to any of the groups based on their distance from the cluster centres (Table 3).

High values of above-ground plant height and corm circumference were characteristics of giant types of cocoyam, while lower values sometimes were markedly traits of dwarfs or medium-stature types. Plant height had a positive correlation with petiole sheath length ($r = 0.773$), petiole length ($r = 0.850$), corm circumference ($r = 0.748$), and above-ground corm height ($r = 0.692$).

Fig. 2 shows the relationship of two yield components of the 10 best-yielding accessions in the cocoyam collection. It has been observed that the number of cormels is the variable with the highest positive effect on cocoyam yield (Agueguia, 1993). However, observations contrary to that assertion were recorded in this study. The best-yielding accession (TA 97 083), which yielded 7 kg of cormels per stand, had an average of 14 cormels, while another accession (SCJ 98 024) with as many as 22 cormels per stand yielded only 3 kg.

TABLE 2

Descriptive Statistics of 78 Accessions of Cocoyam Germplasm at Bunso

Character	*Minimum*	*Maximum*	*Mean*
Petiole sheath length (cm)	19.8	102.4	67.9 ± 2.1
Petiole length (cm)	42.0	162.4	112.1 ± 2.9
Plant height (cm)	55.4	173.8	109.4 ± 2.9
Corm circumference (cm)	15.0	43.3	29.0 ± 0.6
Above ground corm height (cm)	3.1	21.8	8.4 ± 0.4
No. of secondary axillary buds	2.0	13.0	5.3 ± 0.3
No. of cormels/stand	4.4	22.0	11.4 ± 0.4
Cormel fresh weight/stand (kg)	0.3	6.6	1.4 ± 9.3

TABLE 3

Cluster Centres of Some Metric Traits that Relate to Plant Size

Character	*Cluster 1*	*Cluster 2*	*Cluster 3*	*Cluster 4*	*Cluster 5*
Petiole sheath length (cm)	19.8	42.4	56.3	67.1	88.9
Petiole length (cm)	125.6	73.8	145.0	110.0	136.8
Lamina length (cm)	49.0	29.0	61.0	39.0	51.0
Lamina width (cm)	49.6	26.6	60.9	36.9	49.3
Corm circumference (cm)	35.0	22.5	35.8	35.8	28.0
Above ground corm height (cm)	13.0	5.2	12.1	7. 6	11.4
Plant height (cm)	120.0	76.7	146.0	101.9	139.8

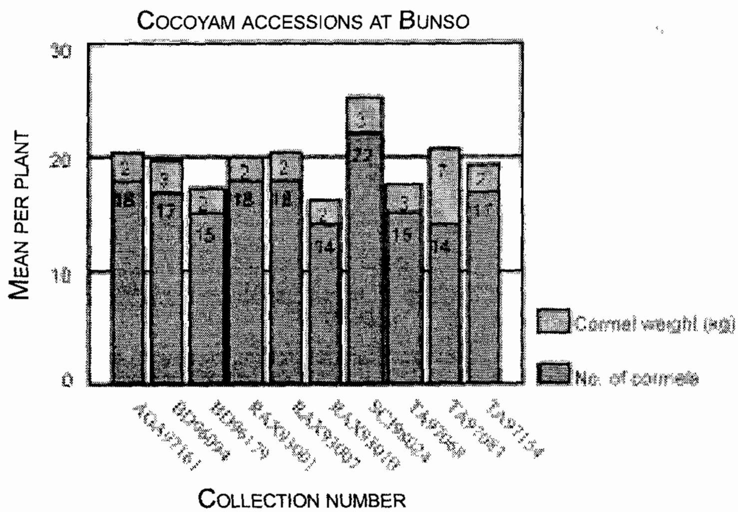

Fig. 2. Relationship of two yield components in 10 best cocoyam accessions at Bunso.

Similarly, the two accessions with the second highest number of cormels (18) had only 2 kg per stand. In this situation, size of cormel appeared to have a greater impact than numbers.

Conclusion

Eight different groups of cocoyam have been identified in this study. Some unexpected groups have been formed based on morphological data. Polymorphism was not observed in eight of the qualitative characters while 20 others showed polymorphism, with cormel cooking quality being the highest. Field observation and quantitative traits offered sufficient reason to use plant size as a reliable distinguishing character. The cocoyam variability as observed, plus available ethnobotanical information suggest that five different types of cocoyam can for convenience be called 'Red giant', 'Red medium',' Hard white', 'Soft white I' (medium soft), and 'Soft white II' (very soft).

Some cocoyam diversity is suspected to be lost, because the yellow flesh type, 'Amankani antwibo', and the white type with constricted cormels have, in the main, not been found in the recent collections.

Recommendation

The available germplasm should be studied further with molecular tools to identify any further variability. Measures should be put in place to conserve what is left of cocoyam diversity, and enquiries should be made in other neighbouring countries with similar climate as Ghana, for a possible recovery of cocoyam genotypes that are suspected to have been lost in Ghana.

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