Mineral nutrition of cashew
(*Anacardium occidentale* L)

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INTRODUCTION

Cashew (*Anacardium occidentale* L.) is an evergreen perennial tree which in favourable conditions grows to 10–15 metres (m) height and under moderate conditions grows to 5–6 m in about six years with a spread of about 4 m.

Distribution of cashew extends up to 27°N and 28°S latitudes (Joubert and Thomas, 1965). Cashew tree has a very well developed fast growing root system with wide network of primary and secondary roots providing the tree with their mineral requirements in poor soils and, water in seasons of drought (Ohler, 1979; Agnolini and Giuliani, 1977).

SOILS

Cashew being a hardy plant can thrive in a variety of soils and is usually found alloted to marginal wastelands. The crop grown widely in the coastal belts of South India till 1950 were mostly used for fuel purposes. Interest in this crop is of recent origin and it has already proved its tremendous potential.

A deep friable well drained sandy loam soil without a hard pan and with subsoil water at 5–10 m depth is considered to be ideal for cashew. But it is found growing well in coastal sand, or laterite or red soils and to a limited extent in the black soils of South India, volcanic soils of Philippines, Indonesia and Fiji Islands, alluvial soils of Sri Lanka and Philippines and the ferrugenous and ferralitic soils of East and West Africa, Sri Lanka, Brazil and Malagasy (Ohler 1979; Nair *et al.*, 1979; Agnolini and Giuliani, 1977). Heavy clayey soils though fertile, poorly drained soils or those subjected to stagnation of water, flooding or too high water table are not suitable for cashew as they restrict its vigorous root system to superficial growth. Thus physical properties of the soil are suggested to be of much more importance for the success of the crop than even high fertility. (Nair *et al.*, 1979; Ohler, 1979; Agnolini and Giuliani, 1977). Due to its hardy drought resistant nature it is also found grown on hill slopes, too stony and too dry for other crops (Purseglove, 1977). Under laboratory conditions cashew indicated only little tolerance to salinity, but tolerance varies between trees and they are found to grow very near the sea coast also (Ohler, 1979). Cashew is grown extensively in coastal sandy areas and in light soils of India, Tanzania, Mozambique and Brazil but when grown in laterite soils or with a hard sub soil as found in many areas of South India, cashew shows lower rate of growth (Agnolini and Giuliani, 1977).

Cashew prefers slightly acid soil of pH 4.5 to 6.5, with low calcium content (Agnolini and Giuliani, 1977). Very acid soils are sometimes limed (Ohler, 1979). A rating chart for land selection in Orissa for cashew was prepared by Mahapatra and Bhujan (1974) and such information if prepared for various regions, should prove useful.

NUTRITIONAL STUDIES

Relegated as a waste land crop the only maintenance usually accorded to the cashew is protecting the young plants and later collecting whatever nuts annually available from the trees. With the recognition of the tree as a paying crop, efforts have been made to study its nutritional requirements.

At the time of planting addition of wood ash to the planting pit particularly that of cashew rich in potassium, as a practice has been reported (Agnolini and Giuliani, 1977). A minimum of 10 kg of organic manure is said to be mixed with the soil in the pits at the time of planting in Brazil. In India, manuring of planting pits for cashew is not practised (Agnolini and Giuliani, 1977). Ammonium sulphate (6 oz), double superphosphate (3 oz) and potassium chloride (3 oz) broadcast around each cashew seedling at Nachingwea (Tanzania) did not give any response, but at Majunga in Malagasy, 16 g N, 40 g P, 36 g K applied to seedlings was found to increase its vigour seven times over that of control. An NPK mixture (11 : 22 : 16) at 200 to 300 g per plant annually worked into the surface soil during the first two years has been suggested for cashew (Agnolini and Giuliani, 1977).

Selection of seeds for high vigour can produce vigorous seedlings (Menon *et al.*, 1978). If their well developed fast growing root system is provided with suitable physical soil conditions, the young plant with its limited requirements should be able to thrive as well and flourish without manure application in the planting pit. Further, such application is likely to restrict the initial growth of the roots to within the close limits of the base. It may be worthwhile to make detailed studies in this respect before giving a recommendation.

Harishu Kumar and Nair (1980) in a study of fluctuations in nutrient uptake pattern during the various months at Vittal in South India found that cashew plants in the region felt the stress for nutrients from April to July and recommended half the annual dose of manure to be applied in May-June and the rest in October–November.

The amount of nutrients removed from soil by a mature bearing cashew tree per annum for its maintenance (Table I) has been worked out (Mohapatra *et al.*, 1973). A manuring schedule for cashew of different age groups has been given by Rai in 1969 (Table II). In their package of practices recommended for boosting production of cashew, a schedule for manuring (Table III) has been given by Central Plantation Crops Research Institute, Kasaragod, India (Rao, 1974). Under sandy soil conditions of Bapatla in the East Coast of South India, annual application of 1 kg of N per cashew tree is reported to have been recommended (Rao, 1974). Studies in Malagasy showed that N and P are required by cashew in earlier stages for better growth and earlier flowering (Table IV). In another trial from Malagasy cashew plants were given 200, 400 and 600 g of N P K mixture (11 : 22 : 16) in 1st (at the planting hole), 2nd and 3rd year, and in 4th year 400 g of the mixture before rainfall and separate treatments after rainy season (Table V). Additional amounts of N and K were found to increase the yield but results from Tanzania showed that fertilizer application increased cashew yield only in poor soils (Ohler, 1979).

In India a spacing-cum-manurial-cum-mulching trial was laid out in 1958–59 at Vengurla and the yield data summarised for 1970–74 showed that the highest dose of 50 kg N per hectare and planting at a spacing of 7.2 m gave the best response. A linear response was noted with farm yard manure in all spacings but closer spacings gave higher yields. Mulching was found to have no significant effect on yield (Damodaran *et al.*, 1979). At Vridhachalam, trial with farm yard manure, N,P and K showed that 25 kg of F.Y.M. with 600 g N per cashew tree gave significant increase in yield. In another trial at Kasaragod during 1972–75, N at 300 and 500 g per tree per year was found to increase yield in cashew while P and K had no effect on yield (Damodaran *et al.*, 1979). In a trial initiated at Vengurla in 1969, N and P was found to increase yield and vigour of cashew tree but there was no response for K application. There was good response to N at 135 kg/ha in presence of P (50 kg/ha) and K (100 kg/ha) and this response was limited to 75 kg in the absence of P and K. Similarly response to P was also restricted to only 25 kg at low levels of N (25 kg to 75 kg/ha). Response of P increased as levels of N increased to 125 kg/ha. Effect of N and P interaction was also observed on yield and vigour of cashew tree but at their higher levels, response was controlled by K application (Sawke, 1980). At Orissa, in the East coast of India, old cashew plantations responded only to nitrogen and 250 g per plant was found to be the optimum dosage (Mishra *et al.*, 1980).

Foliar spray with urea at 10 to 15% with 0.1% endosulphan at Kasaragod did not give any significant results (Nambiar, 1977). At Vridhachalam, in a trial in 1976, 3% urea with 0.05% endosulphan in 2 and 5 sprays gave higher yields while endosulphan alone without urea when increased from 2 to 5 sprays also gave higher yields (Nambiar, 1977). A similar trial in Bapatla gave no response to foliar application of urea with endosulphan on cashew (Nambiar, 1977). But 1% urea spray in split doses in July and November had been reported to increase vigour of cashew trees in Bapatla (Anon., 1967–68).

The root system of cashew fully exploits the fertile top 30 cm and spreads far outside the canopy of the tree (Ohler, 1979). Application of manure in trenches or basins around the tree may restrict growth of its normal vigorous root system. It may thus be advisable to broadcast the manure around the cashew in widening circles year after year (Ohler, 1979). At Nachingwea fertilizer spread over the surface did not give any significant yield (Agnolini and Giuliani, 1977). Application of manure in split doses to cashew gave better yield than as single dose (Ohler, 1979). In Malagasy, application of fertilizer in single dose in planting hole is reported to have given very vigorous growth during the first two years after planting (Agnolini and Giuliani, 1977).

The cashew grown in west coast of India are mostly on undulating terrain subject to heavy rainfall, and manure if applied by broadcasting is likely to get washed off. In a trial at CPCRI, Vittal in South India, application of fertilizers in double trenches 30 cm deep and 30 cm wide at 1.5 m and 3 m away from the base of the tree was found to enable quicker absorption and more accumulation of all three major nutrients and their maintenance for longer periods in the leaf tissue than by application in small pits (30 cm × 30 cm, 4 nos.) dug around the tree or broadcasting (Harishu Kumar and Nagabhushanam 1981).

DEFICIENCY SYMPTOMS

Symptoms due to deficiency of mineral nutrients induced in cashew seedlings have been studied (Falade, 1978; Ohler and Coester, 1979) under laboratory conditions. Very low and high levels of macronutrients resulted in stunted growth and had appreciable effect on the absorption, translocation and distribution of nutrients in cashew (Falade, 1978).

Nitrogen: Under low levels of N there was a general reduction in size and yellowing of leaves beginning with older leaves which later spread to younger ones. Colour of the petioles tended to turn reddish in colour, and development of these symptoms coincided with stagnation of growth (Falade, 1978, Ohler and Coester, 1979). Very low and high levels of N also reduced dry matter accumulation of the plant, while high levels of N made cashew leaves dark green, succulent and glossy (Falade, 1978). Ca and K in all parts, Mg in roots, S in stem and leaves and Na in leaves first increased to maximum before falling with increasing levels of N in nutrient solution (Falade, 1978).

Phosphorus: Leaf colour changed to dark green with deficiency of P for the first three months and in the next two months slowly changed to bronze green to yellowish shade. Lower leaves at this stage withered and growth of the plant ceased much earlier (Ohler and Coester, 1979). They also mentioned that during early stages slowing down of growth with P deficiency was reported by Avilan and Brasil. With increase of P level, N, P and K increased in all parts. Ca in leaves, whole plant and roots; Mg in leaves, roots and stem and S in all parts increased first and then decreased with increasing levels of P. Translocation rates of N, P, S and Mg first increased before falling with increased levels of P application (Falade, 1978).

Potassium: Deficiency symptoms of K developed slowly, with lower leaves first turning yellow at the apex and along the margin. As the deficiency advanced, a characteristic elongated green section developed at the base of the leaves, and along the mid rib in an inverted 'V' shape, and the rest of the leaf turned yellow with a necrotic tip (Ohler and Coester, 1979). With increasing K level in the nutrient solution, K, P and Na in all parts, and N and Ca in roots increased. The level of Mg in stem increased to the highest before falling with increasing level of K (Falade, 1978).

Calcium: Deficiency symptoms of Ca developed early but then progressed slowly with youngest leaves first turning yellow, narrow in shape and smaller in size, while the basal leaves became light green or developed yellow patches which later coalesced. The top leaves developed wavy margins curving inward in between the veins. Development of laterals on Ca deficient plants was also reduced (Ohler and Coester, 1979). With increased levels of Ca in nutrient solution, concentration of N, S and Ca in all parts and Na in stem of the plant first increased to a maximum before falling. Magnesium decreased initially before increasing with higher Ca levels (Falade, 1978).

Magnesium: Deficiency of Mg in the nutrient solution developed characteristic yellowing of lower leaves with their tips and margins remaining green for some time. These symptoms developed within one month and then rapidly spread towards the top of the plant resulting in its death within two and a half months. Development of laterals was also reported to be reduced in Mg deficient cashew plants (Ohler and Coester, 1979). With increasing Mg in the nutrient solution Na and S in all parts, Ca in stem and P in stem and leaves of the plant increased to a maximum and then fell. Mg and N increased in all parts and Na and P in whole plant with increasing levels of Mg (Falade, 1978).

Sulphur: Sulphur deficiency symptoms developed within one month, with the terminal leaves turning chlorotic beginning from the tip. Later the colour gradually changed from green to yellow with a reddish yellow apex. Petioles and mid-ribs of some leaves also showed this reddish discolouration. In advanced stage, necrosis of the terminal leaf tip and margins developed with older leaves showing pinkish brown patches between its main veins. Sulphur deficient plants were dwarf, without any lateral shoots and the growth of the plant stopped within 2½ months of inducing deficiency of sulphur (Ohler and Coester 1979). Sulphur content increased in all parts and Na in stem and roots also increased with increasing levels of S. But in whole plant and leaves Na increased initially to a maximum before falling with increasing S level in nutrient solution (Falade, 1978).

Iron: Deficiency of iron (Fe) caused severe chlorosis early, ending in the death of the plant within 7 weeks. By four months, young leaves excepting mid rib and main veins and top portion of the stem turned yellow to whitish yellow. Younger leaves were narrow and the basal leaves changed to yellowish green in colour (Ohler and Coester, 1979).

Boron: Deficiency developed slowly and by fifth month youngest leaves showed poor development with narrow shape and sometimes were curled or distorted. Lateral shoot development was not affected by B deficiency (Ohler and Coester, 1979).

Manganese: Youngest leaves became pale green in colour within six weeks of inducing Mn deficiency in nutrient solution and they later turned to yellowish green in colour with green band along the mid-rib and main veins. Some of the leaves had brown margins and by fifth month rosetting and premature withering of young leaves could be observed. The deficient plants did not grow tall but developed many small laterals (Ohler and Coester, 1979).

Zinc: Most of the top leaves of the deficient seedlings within 10 weeks of the experiment changed their colour from green to pale green and then finally to yellow with green veins. The youngest leaves had a reddish brown colouration and tended to be narrow and some were sickle shaped. Number of laterals produced were reduced in deficient plants (Ohler and Coester 1979). Zinc deficiency in cashew plantations of Dakshina Karnataka district in S. India has been observed (Subbaiah and Joshi 1981). Reduction of size, distortion of shape and drooping of leaves were the symptoms observed, which could be controlled by foliar application of zinc.

Copper deficiency did not produce any prominent symptoms other than the leaves turning darker green with slightly reduced development of younger leaves by fifth month of the experiment. Leaves of seedlings deficient in molybdenum after six weeks of the experiment became mottled green which later changed to yellowish green with green veins. Some of the younger leaves were reddish brown and the seedlings had strong development of lateral shoots. Some of the plants suffered from premature drop of terminal leaves ending up in their sudden death (Ohler and Coester, 1979).

Ohler and Coester (1979) grouped the minerals into three groups viz: (*a*) Fe, Mg, K, N and Mo, deficiency of which proved lethal during the trial in the order of severity, (*b*) S, Ca, Mn, and Zn deficiency, symptoms of which developed early but were not lethal and (*c*) P, B and Cu deficiency, symptoms which developed slowly and were not severe in their effects. Falade (1978) reported the synergestic and antagonistic effects of various elements on cashew seedlings under laboratory conditions. Ohler (1979) mentioned about zinc deficiency symptoms observed by Lefebvre in the field itself. Yellow leaf spot of cashew widely found to occur in the west coast of South India (Menon *et al.*, 1979) is possibly due to deficiency of a single or combination of mineral nutrients. Ohler (1979) referred to a symptom of leaf necrosis observed in cashew in Kenyan coast by Adams *et al.*, in 1977 which was found to be due to Fe deficiency in a physiologically utilizable form. Though the deficiency of the nutrients may not be that severe to manifest itself on the cashew tree, it is likely that the heavily leached soils as found in the west coast of South India may lack in nutrients limiting the yield performance of the trees. Deficiency symptoms develop only when it is most severe, and in the field it is essential that level of nutrients is not allowed to reach that low status.

LEAF ANALYSIS

In addition to the complex relationship of a tree crop to climatic and soil factors, the cashew with its hardy nature growing in a variety of soil and climate, mostly under neglected conditions is so versatile that it should be a problem to predict its nutritional requirements with any certainty. Tissue analysis as a diagnostic technique to study the nutritional requirements of cashew may prove useful in such conditions. Further, leaf analysis has the advantage over soil analysis in that it reveals the actual amounts of nutrients absorbed by the plant and the interpretation is not dependent on the availability of the nutrient in soil or its exchange capacity. Leaf analysis as a means of evaluating nutritional status of tree crops like coconut, cocoa, apple, citrus, mango etc. has been reported by various authors. The technique of foliar analysis has also been dealt in detail (Chapman, 1964, Smith, 1962).

From Malagasy, Lefebvre (1973) reported data on leaf analysis of apparently healthy and affected cashew trees (TableVI). Calton *et al.* earlier in 1961 also had given figures for similar trees (TableVI). The low con-

PLATE I

A close up of cashew with fruits at University of Agricultural Sciences, Bangalore

PLATE II

Cashew fruit bunches with 25 to 35 fruits per bunch at Bangalore

tent of N, P, K, Fe, Mn and Cu in unthrifty trees was suggested to be due to the wet and poor physical conditions of the soil interfering with their uptake by the roots.

Harishu Kumar *et al* (1982) reported higher N, P, K content in cashew leaves after fruiting season (Table VII) but leaves from the top and bottom half of the tree did not show any significant difference in these mineral contents. Fully mature leaves of the current seasons growth had significantly higher N, P, K contents in post fruiting period (Table VIII) compared to the pre-fruiting season. Harishu Kumar and Nair (1980) inferred that leaf sample collection from three composite samples of five trees per sample during pre-fruting season, and six composite samples of 3 trees during post-fruiting season would be enough from one hectare area.

Harishu Kumar and Nair (1980) studying the fluctuations in nutrient uptake patterns analysed fully mature leaves of cashew at monthly intervals. N content was lowest at the end of fruiting season in April to July (1.008%) when it started increasing gradually till October and reached the highest figure of 1.634 in December. After flowering in January the N content gradually decreased and touched the lowest in April. P content was steady from May to October (0.069%). In December just before flowering P content of cashew leaves reached a peak of 0.121% which then steadily declined. K content was lowest in August (0.383%) which steadily increased afterwards and reached the peak in February (0.710%). The N/P and N/K ratio was low from February to June when the trees were in fruit and rainfall was minimum. Diversion of the minerals to flowers and developing fruits which act as sinks is likely to be the reason that they are found low in the leaves during the reproductive season.

From Malaysia also it was reported that N, P, K content in the cashew leaves in wet season are higher than in dry season which should coincide with the fruiting season (Yacob *et al.*, 1979).

In a sand culture study (Harishu Kumar 1981) aluminium was found to stimulate the growth of cashew seedlings, increase the dry matter content of root and shoot, and increase the length of roots (Table IX). In the same study it was also found that aluminium induced phosphorus mobilization from root to shoot.

Leaf analysis of cashew to judge its nutrient requirements could be of much use in its proper maintenance. The nutrient status of the leaf tissue will not be representative of the soil. Much more intensive studies are required on these relationships before this information can be put to actual use.

The available data of manurial requirements of cashew is highly varying and general conclusions are very difficult to arrive at for a manurial schedule to be followed for cashew. It is further made difficult as the cashew population is highly heterogenous and grown under a variety of agroclimatic conditions. Around Bangalore in South India with less of humidity, temperature and rainfall compared to the coastal regions, the existing stray cashew plantations are found to grow vigorously on laterite soils, and though no records are available on its yield the trees are found to bear heavily without any manuring or other attention. Panicles with as many as 35 mature nuts are commonly noticed in some of these trees (Plate 1 and 2) With its highly developed root system even in poor soils cashew thrives well, but under such limitations, judicious application of manures would evoke good yield response.

Association of mycorrhizae with roots of cashew has been observed in Bangalore (Joshi, 1980). With the help of mycorrhizae, trees are found to grow better and in most sites appear to be required for the tree survival (Kramer and Kozlouski, 1979). Through their exclusive mycelial. net work in the soil and hyphae of the mycorrhizae radiating into the soil, absorbing surface in the soil may enlarge to as much as thousand times that of a root lacking this fungus (Larcher, 1975).

Cashew is a hardy tree by nature suited to dry regions of poor fertility and provided with qualities to thrive under unfavourable conditions. Domestication by way of cultivation and application of fertilizers of the crop should not hamper the natural hardiness of the crop. N and P seems to be mainly required soon after planting and as the growing plant matures and starts yileding, increased requirement of K is indicated. Careful study of the inherent ability of cashew in absorbing and utilizing mineral nutrients, and probable role of soil microflora in its nutrition is required for a proper assessment of the nutrition requirement of this versatile crop.

TABLE I

NUTRIENTS REMOVED IN KG BY A CASHEW TREE (MOHAPATRA *et al.*, 1973)

Nutrient removal (kg) by growth and production	N	P (as P_2O_5)	K (as K_2O)	Average NPK ratio
Vegetative part including roots and stem	1.721	0.406	0.800	4 : 1 : 2
Apples (155 kg)	0.370	0.117	0.282	3.2 : 1 : 2.4
Nuts (24 kg)	0.756	0.229	0.183	3 : 3 : 1 : 0.8
Total	2.847	0.752	1.265	3.8 : 1 : 1.7

TABLE II

SCHEDULE FOR APPLICATION OF FERTILIZERS FOR CASHEW (RAI, 1969)

Fertilizer recommended kg/acre of 100 trees	Below 3 years	3 to 6 years	Above 6 years
Sulphate of ammonia	16	32	64
Superphosphate	25	50	100
Muriate of potash	5	10	20

TABLE III

FERTILIZER SCHEDULE FOR CASHEW (CPCRI, 1974) (FOR TREES YIELDING 5 KG OF NUTS PER YEAR)

Stage of growth	May–June (kg/ha)			September–October (kg/ha)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1st year	100	80	—	50	40	—
2nd year	50	40	30	50	40	30
3rd year	100	60	60	100	60	60
4th year onwards	125	60	60	125	60	60

TABLE IV

CASHEW SEEDLINGS FLOWERED (PERCENTAGE) WITH AND WITHOUT N+P TREATMENT AT DIFFERENT AGES (LEFEBVRE, 1970)

Treatment	2½ years	3½ years	4½ years
N+P	35	87	100
No treatment	0	8	31

TABLE V

YIELD IN KG OF FOUR YEAR OLD CASHEW TREES WITH DIFFERENT FERTILIZER APPLICATIONS (LEFEBVRE, 1973)

Application	Third year	Fourth year	Per-centage increase	Tota yield (kg/ha)
Control	20.8	22.5	8	450
N	18.0	30.5	70	610
P	19.7	25.7	31	515
K	21.6	31.2	44	626
NP	20.0	28.0	39	559
NK	18.5	36.0	95	710
PK	22.4	24.1	8	482
NPK	20.6	32.7	59	655
NPK+trace elements	19.8	32.6	64	652

N=0.050 kg; N, P=0.100 kg; P_2O_5, K=0.075 kg; K_2O and mixture of trace elements.

TABLE VI

RESULTS OF FOLIAR ANALYSIS OF CASHEW TREES

	Calton *et al.* (1961) Thrifty trees	Calton *et al.* (1961) Unthrifty trees	Lefebvre (1973) Healthy trees
Macronutrients (%)			
N	1.98	1.52	1.73
P	0.21	0.10	0.082
K	1.69	0.97	0.88
Ca	0.09	0.16	0.284
Mg	0.20	0.17	0.163
S	0.15	0.14	—
Micronutrients (ppm)			
Ca	16	66	5.7
Fe	45	95	87.0
Mn	95	260	174.0
Zn	—	—	20.0
B	9	10	—

TABLE VII

EFFECT OF SEASON ON N, P, K CONTENTS OF CASHEW LEAVES (Harishu Kumar *et al.*, 1982)

Season	N(%)	P(%)	K(%)
Pre-fruiting	1.4127	0.0930	0.6277
After fruiting	1.4872	0.1215	0.7927
t value	2.0262*	3.6717**	4.4807**

** Significant at 1%

* Significant at 5%

TABLE VIII

EFFECT OF AGE ON NPK CONTENTS OF CASHEW LEAVES

Season	Age group	N(%)	P(%)	K(%)
Pre-fruiting	Fully matured leaves of previous season ..	1.4885	0.0835	0.5970
	Freshly matured leaves of current season ..	1.3370	0.0875	0.6585
After fruiting	Fully matured leaves of previous season ..	1.1855	0.0625	0.4605
	Freshly matured leaves of current season ..	1.7890	0.1790	11.1250
t value		13.2343**	16.5637**	32.8493**

TABLE IX

GROWTH CHARACTERISTICS AS INFLUENCED BY ALUMINIUM (MEAN OF FOUR REPLICATIONS) (Harishu Kumar 1981)

Al conc. (mg/l)	Shoot length (cm)	Shoot dry matter (g)	Root length (cm)	Root dry matter (g)
0	41.00	6.095	13.00	1.555
4	38.75	7.942	22.00	2.060
8	43.25	8.935	17.25	2.0005
12	46.25	8.942	17.50	2.015
16	44.00	7.482	18.50	2.190
LSD(0.05)	NS	1.380	3.21	0.574

NS=Not significant

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