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Evaluation of Agronomic Performance of Maize (*zea mays l.*) under different rates of NPK Fertilizer Application in an ultisol of Lafia, Nassarawa State

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ABSTRACT

The study was carried out in Lafia, Nassarawa State with the view to determine the optimum fertilizer rate for maize production among the Ultisols. The hybrid maize, Oba super II was used as a test crop while commercial NPK (15:15:15) fertilizer at the rates of 0: 0: 0, 60: 30: 30, 90: 45: 45, 120: 60: 60 and 150: 75: 75 kg/ha representing 0.48, 0.72, 0.96 and 1.20 kg/ha were applied to the hybrid maize, "Oba super II". The soils were well drained with sandy loam texture while structural aggregates were poor to weak. The soils were low in cation exchange capacity, basic cation (Ca, Mg, K and Na), total nitrogen, available phosphorus and organic carbon. They were low in micronutrient and therefore, low in their inherent fertility status. Uptake and utilization of applied fertilizer in both years witness better responses compared with the non-fertilized plants. NPK 60:30:30 kg/ha yielded highest (65.60 cm and 13.14) plant height and number of leaves while leaf areas and leaf area index were highest (5.52 m2 and 0.46 m2) at NPK 120:60:60 kg/ha. The stem diameter was highest (94.50 mm) with the use of NPK 150:75:75 kg/ha. In terms of yield parameters, ear weight and ear length were highest (90.00 g and 10.64 cm) at NPK 150:75:75 kg/ha while ear diameter and grain yield were highest (123.94 cm and 1.06 kg) with the use of NPK 90:45:45 kg/ha Grain yield advantages were successfully maximized with the use of NPK 90:45:45 Kg/ha

1. Introduction

Maize (*Zea mays L.*) is the third most important cereal after wheat and rice (Jones, 1997). The crop is commonly cultivated in the tropics and warm sub-tropics for food, livestock and industrial uses. In Nigeria, maize is an important food, fodder and industrial crop grown both commercially and at subsistence level (Eleweanya *et al.,* 2005). Maize is used for the production of indigenous and commercial food products that are relished for their unique and distinctive flavours. Its demand for domestic consumption, economic growth, ceremonial purpose and export for foreign exchange return is high along with low production and discouraging yield. Efforts aimed at obtaining high yield of maize would necessitate the augmentation of the nutrient status of the soil to meet the crop's requirements for optimum productivity and maintain soil fertility. Increasing the nutrient status of the soil may be achieved by right information on distribution, potential and constraints of major soils; so that the most appropriate soil management systems can be designed. Also, knowledge on soil taxonomic classification is essential to boosting the soil nutrient content either with the use of inorganic fertilizers such as NPK or through the use of organic materials.

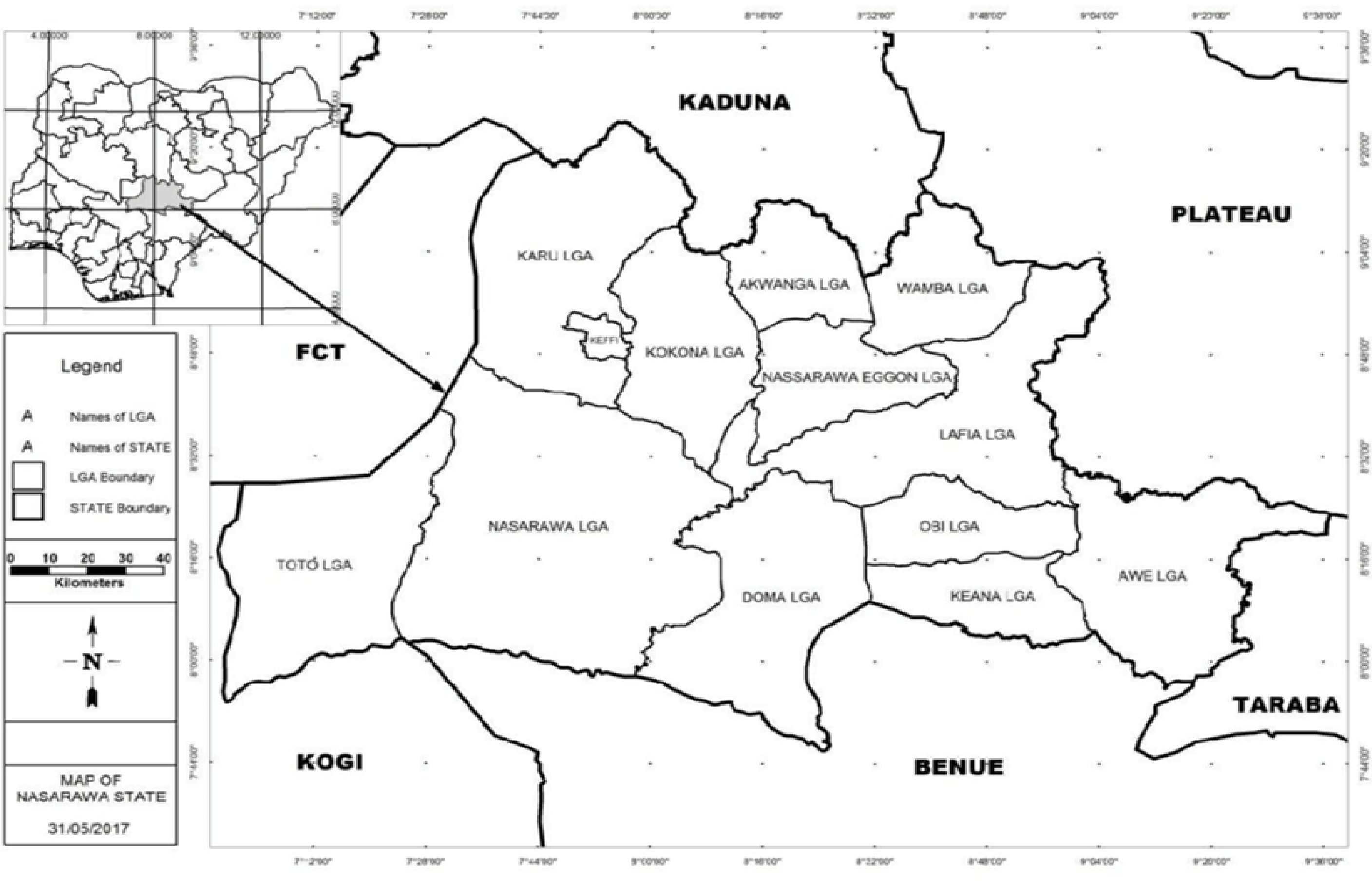
Maize crop requires an adequate supply of nutrients particularly nitrogen, phosphorus and potassium for optimum growth and yield. Being a heavy feeder of nitrogen, adequate supply of nitrogen can be a limiting factor closely associated with its yield magnitude (Akintoye, 1997). The amount required of these nutrients particularly nitrogen depends on a number of factors including soil type, previous vegetation cover/cropping history, tillage method , crop variety grown, rainfall, organic matter content, CEC and light intensity (Kang, 1981; Pal, 1991; Ezeaku, 2001).

Also, the unavailability and increasing cost of inorganic fertilizer calls for efficient fertilizer use as against blanket application currently practiced. It is on the bases of differences in soil morphology, physical and chemical characteristics that soils are classified. Knowledge of soil properties will significantly aid in the management of the soil. Since different soil types varied in nutrient status, it is therefore, important to ensure the required quantity of fertilizer (nutrient) be supplied to specific soil type in order to minimize cost and optimize crop yield. Thus, the aim of this study is to determine the optimum fertilizer rate for maize production in Ultisols of Lafia.

2.0 MATERIALS AND METHODS

2.1 *Experimental Site :* The studies were conducted during the 2017 and 2018 season at the Teaching and Research farm of the Department of Agriculture, College of Agriculture, Lafia, Nassarawa State. The study area lie between latitude 8^0 25'N to 8^0 34' 15N and longitude 8^0 24'E to 8^0 38'E in the guinea savannah region of northern Nigeria. The geology of the areas comprise of cretaceous sediments of predominantly sandstone and shale; and Precambrian granites, gneisses and magnatites of the basement complex. The major physiographic units of the study areas consist of undulating plains, hills and lowlands and the differences between them reflect the underlying geology.

Figure 1: Map of Nassarawa State showing the study area



Source: https://www.researchgate.net

Annual rainfall of the areas ranged from 1100 mm to about 2000 mm, and its distribution is characterized by two peak periods (July and September) separated by a short August break.

2.2 Field work

Reconnaissance soil survey was carried out to identify the soil type of the experimental site. To select such soils, available Soil Map and the Reconnaissance Soil Survey of Nigeria Soils Report of the study sites by FDALR, (1990) were employed. Auger samples of the soil was collected and analyzed in the laboratory for particle size distribution, exchangeable cation, cation exchange capacity (CEC) to determine percentage base saturation. Profile pit was sunk in the experimental site during the first and second year of the research (that is before the start and after the experiments).

2.3 Soil Sample Collection and Preparation

Soil samples were collected from the profile pit according to horizons, air-dried, crushed and sieved through a 2 mm mesh sieve. The sieved samples were then subjected to laboratory analysis using the Manual of Selected Methods of Plants and Soil Analysis, IITA, (2015). The soil samples were analysed for their physical and chemical properties using standard soil analytical procedures.

2.*4 Laboratory Analysis*

The soil samples were analysed using standard soil analytical procedures. The particle size distribution (PSD) was determined using Buoyoucos hydrometer method as described by Day (1965). Soil reaction (pH) was determined using the electrometric method using pH meter in 1:1 soil: water ratio as described by Hesse (1971), and organic carbon was determined using the Walkey-Black method as described by Hesse (1971). The Macro Kjeldahl method was used to analyze for total N, while the Bray I method as described by IITA (1979) was used to analyze for available P. Exchangeable cations (Ca, Mg, K, Na) were determined from NH_4OAC filtrate. Exchange acidity was determined using the Barium chloride-triethanolamine method as described by Peech (1965). CEC was determined by IITA (2015) procedures while the percentage base saturation was calculated by dividing the sum of exchangeable bases over the effective cation exchange capacity and multiplying by 100.

2.5 Crop Sampling and Data Collection

Central row plants were used for data collection. Ten (10) plants from the middle rows were used to compute the score for each plot at 4, 6 and 8 WAP. The mean from the 10 randomly selected plants from the middle rows were taken as the score for each plot. Growth parameters such as, plant height, number of leaf per plant, leaf area per plant, leaf area index, and stem diameter; yield components such as, ear weight, ear length, ear diameter, and grain yield were recorded 14 WAP.

2.6 Statistical Analysis

Data collected on various growth and yield parameters were subjected to analysis of variance techniques using statistical analysis system software (SAS, 1997). The treatments means were separated using LSD test at 0.05 probabilities.

2.7 Crop Management

Land area of 26 m x 21 m was cleared, harrowed and ridged. The prepared plot was sub divided into treatment plots (3 m x 4 m) with a border of 1 m between plots. The experiments were laid out in a Randomized Complete Block Design (RCBD) with five replicates per treatment. Improved maize variety (Orba Super II Hybrid) was used for the experiment. Maize seeds were planted in each of the treatment plots (3 seeds per hole) at a spacing of 90 cm x 50 cm between and within rows (that is inter row and intra row spacing). Prior to seed germination, the experimental areas were sprayed with Atrazine (pre-emergence) so as to suppress weed invasion. After germination, the maize seedlings were thinned to two seedlings per hole. NPK (15 : 15 : 15) fertilizer was obtained and used for the experiment. Two weeks after planting, the maize seedlings were ring-dressed with the respective fertilizer rates according to the treatments indicated above. Varying fertilizer rates were based on 0 : 0 : 0 kg/ha, 60 : 30 : 30 kg/ha, 90 : 45 : 45 kg/ha, 120 : 60 : 60 kg/ha and 150 : 75 : 75 and replicated five (5) times. These were carried out at two equal splits at 2 and 5 weeks after planting (WAP) using ring method. The first as basal application and the second as top dressing using urea. The basal application was such that rate of P and K was wholly applied along with half of N while the remaining N dosage was used as top dressing using urea. All other agronomic practices like hoeing, weeding, and pest control were kept normal for all the treatments.

3.0 RESULTS AND DISCUSSION

3.1 Soil Characteristics

The soil reaction or pH of the soil in the study area ranged from 4.69 to 5.43 averaging 5.06. This value was rated strongly to moderately acid. The strongly to moderately acid reaction of these soils may be caused by the high rainfall experienced in this locality and further complicated by the coarse textured nature of these soils permitting extensive leaching of basic cations. The soil also had high pH at the surface than the subsurface as a result of nutrient biocycling and high percentage base saturation at the surface horizon (Idoga and Azagaku, 2005). This could also be accounted for by the direct deposition of crop and vegetable residues on the soil surface and their subsequent decomposition to release basic cations to the soil. Idoga and Ogbu,(2012) attributed the reduction in soil pH with depth to frequent crop harvesting and leaching of bases. Organic carbon content of the soil ranged from 1.66 to 1.86 gkg^{-1} (Table 1). According to the ratings of Agboola and Ayodele, (1985) and FMANR (1990), these values were rated low and generally did not follow a uniform trend of distribution down the profile. Similarly, total nitrogen was low. Total nitrogen contents were generally less than 1.0 gkg^{-1}. The amount and distribution of total nitrogen correlated positively with that of organic carbon. This is because the two occur in relatively fixed ratios naturally (Ayolagha and Opene, 2012). Loss of N through denitrification and volatilization may also contribute to the low level of N in the area. The low organic carbon content may probably due to continuing cropping for an extended period, bush burning (Kang, 1993), high erosive rate, grazing, harvested crop residues without replacement and very poor management activities (Landon, 1991). Values of the available P in the study area ranged from 2.08 to 2.48 $cmolkg^{-1}$. These values were rated low based on the ratings of Agboola and Ayodele, (1985) and FMANR (1990). The low available P level observed in the study area collaborate the finding of Eshett (1987) who noted that most Nigeria soils have low P reserves. This may be due to strong adsorption of this nutrient by the soil colloids (Kubrin *et al*., 2000). The low P content could also be attributed to the low pH level, which fixed the P and makes it unavailable. It may also be attributed to the low amount of OC, continue cropping, crop removal, erosion of P-carrying particles, P dissolved in surface runoff and leaching due to the coarse nature of the soils.

Exchangeable bases (Ca, Mg, K and Na) were low in all the pedons. Among them, calcium was the most prevalent cation on the exchange complex with values ranging from 1.03 to 1.26 $cmolkg^{-1}$. It may be linked to the occurrence of exchange sites which have a specific affinity to Ca (Idoga, 1985) or because Ca is least easily lost from exchange site or has high displacement ability over other cation in the exchange reaction. Exchangeable potassium ranged from 0.19 to 0.46 $cmolkg^{-1}$ and was rated low. Exchangeable sodium ranged from 0.08 to 0.20 $cmolkg^{-1}$. These values were also rated low. Exchangeable magnesium ranged from 0.45 to 0.80 $cmolkg^{-1}$ and was equally rated low in the study area.

The low exchangeable bases of these soils in the study area may be due to the underlying materials, intensity of weathering, leaching, low activity clay, very low organic matter content and the lateral translocation of bases (Kang and Balasubramanian, 1990; Kang, 1993). The CEC of soils ranged from 3.62 to 4.92 cmolkg^{-1} and had irregular distribution pattern. The soils are therefore, low in their nutrient holding capacities. The low CEC values indicate that the soils had a low potential for retaining plant nutrient. It may also be due to the nature of clay minerals (kaolinite) and low organic carbon level of the soils (Ufot, 2012). The base saturation values varied from 45.5 to 58.1 % which generally, were irregularly distributed. The base saturations were rated low to moderate. A general correlation exists between the percentage base saturation and its pH. As the base saturation is reduced owing to the loss in drainage of calcium and other metallic constituents, the pH is also lowered in a more or less definite proportion. This is in line with the common knowledge that leaching tends ordinarily to increase soil acidity of humid region soils (Ufot, 2012, Brady and Weil, 2014).

3.2 Plant Characteristics

The results of this study showed that different levels of fertilizer application significantly improved the growth and yield of hybrid maize, "Oba super II Hybrid" than the control where fertilizer was not applied. This observation is in agreement with the findings of Babatola *et al*. (2002) who reported that NPK fertilizer application was observed to increased growth and yield of crops. The significant increase in plant height reflects the effect of fertilizer nutrients, N, P and K. The untreated plants were had lower growth as they had to rely on the native soil fertility which, from the result of chemical analysis was deficient in these nutrients. Plant height and stem diameter were highest with the NPK fertilizer rate of 150:75:75 kg/ha while the greater number of leaves, leaf area and LAI in maize occurred at NPK 120:60:60 kg/ha. This could be due to the ability of the fertilizer to supply the nutrient elements necessary to promote more vigorous growth and physiological activities in the plants, as well as improve the soil properties; thereby resulting in the synthesis of increased photo- assimilates that enhanced maize yielding ability. Maize vegetative growth parameters assessed during the research showed that plant height, number of leaves per plant, leaf area, leaf area index (LAI) and stem diameter increased with incremental rates of NPK fertilizer application (Table 2). At 0 kg/ha level of NPK fertilizer application, the mean plant height was 51.80 cm (Table 2). Mean Plant heights increased up to 63.65 cm at the highest NPK fertilizer rate of 90:45:45 kg/ha (Table 2). Also, number of leaves increased up to 12.62 at NPK fertilizer rate of 120:60:60 kg/ha. Similarly, leaf area and LAI steadily increased in all plots treated with fertilizer application relative to the control, indicating that the fertilizer treatment generally enhanced vigorous plant growth. In this study, the highest mean value of LAI (0.46) in the research was also reached with use of NPK 120:60:60 kg/ha. Uptake and utilization of applied fertilizer in both years witness better responses in terms of stem diameter compared with the non-fertilized plants. Increase in stem diameter is a reflection of retention of appreciable amount of assimilates in the stem for leaf production

Table 1: Physical and Chemical Properties of the Soil at the start of the experiment. 2017

Horizon	Depth (cm)	Sand	Silt (%)	Clay	Text. Class	pH H_2O	O.C (gkg^{-1})	O.M (%)	T.N (gkg^{-1})	A.P mg/kg)	Ca	Mg	K (cmolkg^{-1})	Na	TEB	CEC	BS (%)
		Particle Size Distribution									**Exchangeable Cation**						
Ap	0-20	88.00	2.80	9.20	LS	5.43	1.86	3.20	0.07	2.36	1.26	0.78	0.23	0.11	2.38	4.87	48.9
AB	20-56	90.00	2.40	7.60	LS	5.48	1.66	2.86	0.21	2.48	1.15	0.68	0.21	0.20	2.24	4.92	45.5
Bt_1	56-70	83.40	5.20	11.40	SL	5.35	1.66	2.86	0.14	2.39	1.03	0.45	0.20	0.17	1.85	3.62	51.1
Bt_2	70-116	78.00	4.80	17.20	SL	5.05	1.70	2.94	0.14	2.37	1.21	0.76	0.19	0.08	2.24	3.89	57.6
C	116-152	82.00	4.80	13.20	SL	4.69	1.72	2.96	0.07	2.08	1.13	0.80	0.46	0.09	2.48	4.27	58.1

Table 2: Effect of Fertilizer rates on Maize Plant Morphology among the Ultisols of Lafia

Fertilizer Rates (kg/ha)	Plant Morphology				
	Plant Height (cm)	No. of Leaves	Leaf Area (m^2)	Leaf Area Index (m^2)	Stem Diameter (mm)
NPK 0:0:0	51.80±3.09[b]	11.66±0.18[b]	4.12±0.28[b]	0.34±0.02[b]	63.42±2.46[b]
NPK 60:30:30	65.60±2.04[a]	12.58±0.28[a]	5.35±0.21[a]	0.44±0.01[a]	88.02±3.09[a]
NPK 90:45:45	61.82±2.29[a]	12.62±0.21[a]	5.42±0.14[a]	0.45±0.01[a]	90.96±2.58[a]
NPK 120:60:60	61.94±2.56[a]	13.14±0.27[a]	5.52±0.15[a]	0.46±0.01[a]	88.44±2.45[a]
NPK 150:75:	63.65±2.79[a]	12.57±0.29[a]	5.51±0.15[a]	0.45±0.01[a]	94.50±1.96[a]
P-Value	<0.01	0.01	<0.01	<0.01	<0.01

Means on the same column (in each section) with different superscript are statistically significant (p<0.05); ns = not significant

Table 3: Effect of Fertilizer rates on Maize Yield parameter under the Ultisols of Lafia

Fertilizer Rates (kg/ha)	Yield Parameters/Ha			
	Ear Weight (g)	**Ear Length (cm)**	**Ear Diameter (cm)**	**Grain Yield (t/ha)**
NPK 0:0:0	80.60±13.50[b]	9.26±0.78[b]	97.00±11.50[b]	0.68±0.09[b]
NPK 60:30:30	153.00±29.50[ab]	12.32±1.17[a]	168.50±22.40[a]	2.03±0.32[a]
NPK 90:45:45	168.80±28.60[a]	13.20±1.10[a]	181.60±22.30[a]	2.29±0.38[a]
NPK 120:60:60	154.90±25.10[a]	12.68±0.96[a]	171.70±17.50[a]	1.92±0.29[a]
NPK 150:75:	173.00±28.10[a]	13.22±0.88[a]	178.90±18.60[a]	1.77±0.22[ab]
P-Value	*0.04*	*0.03*	*0.01*	*0.02*

Means on the same column (in each section) with different superscript are statistically significant (p<0.05)

Generally, all the traits were very strongly correlated with each other which suggest that, in the case of limited field resources, the performance evaluation of one or more of these traits may provide a reasonable index for the prediction of the probable performance of these other closely associated traits.

The yield characteristics measured were significantly better in all plots receiving fertilizer application than the control treatment where fertilizer was not applied (Table 3) though, no significant differences were observed in ear length and ear diameter between the effects of NPK 60:30:30 to 150:75:75 kg/ha. However, ear weight and grain yield were significantly affected by fertilizer rates. The observed performance in yield parameters with the application of fertilizer could be attributed to the essential nutrient elements contained in the fertilizer that are associated with increased photosynthetic efficiency (Dauda *et al.*, 2008). Studies conducted by various researchers Okoruwa, 1998; Dauda, 2008; Ano, 1991; Obi, 1989; Boateng *et al.*, 2006) have shown that the application of fertilizer both from organic and inorganic sources significantly improves the growth and yield of maize. The highest mean ear weight (173. 00 g) was obtained in plot treated with NPK 150:75:75 kg/ha of fertilizer. Similarly, grain yield was significantly higher (2.29 kg) with NPK 90:45:45 kg/ha (Table 3). The maximum ear weight and grain yield observed during the 2017 and 2018 seasons might be due to the proper dose of NPK being part of the essential nutrients required for the production. The minimum ear weight and grain yield performance however, might be attributed to deficiency of macro nutrients throughout the plant life especially at the time of flowering and seed setting. Generally, the use of fertilizer produced more vigorous maize plants having bigger ear weight than when fertilizer was not applied.

The NPK 90:45:45 kg/ha level of fertilizer application produced an appreciable maize grain yield of 2.29 t/ha (averaged over the two growing seasons) which is within the global average yield of 2.2 to 3.5 t/ha (Okoruwa 1998). The highest grain yield value obtained in this study with NPK 90:45:45 kg/ha fertilizer application is much higher than the average grain yield of 1 t/ha usually reported for West African farmers. Without the application of fertilizer, the average maize grain yield from this study was 0.68 t/ha which is close to the yields generally obtained by peasant farmers who are not able to afford any fertilizer input in this agro-ecological zone.

The fertilizer rate at NPK 90:45:45 kg/ha seemed most satisfactory in obtaining the best maize yield of 2.29 t/ha during the research. Beyond this level (NPK 90:45:45 kg/ha), increases in fertilizer application had no additional advantage on boosting maize grain yield under the Ultisols of Lafia growing conditions, that is the onset of luxury consumption of nitrogen and the production of vegetative growth at the expense of high grain yield occurred beyond a NPK fertilizer rate of 90:45:45 kg/ha.

4.0 Conclusions

From the above results, it could be concluded that yield advantages were gained by cultivating maize in Ultisols of Lafia with fertilizer, albeit at moderate application rates. The yield potential by farmers in this study area can be successfully maximized with the application of NPK 90:45:45 kg/ha.

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