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Effect of nano DAP on growth and yield of maize (*Zea mays* L)

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Abstract
A field experiment was conducted to study the effect of nano DAP on growth and yield of maize (*Zea mays* L.) at the Experimental Block, College of Agriculture, Bheemarayanagudi during *kharif* 2023.The experiment was laid out in split plot design with three RDF levels (50, 75 and 100% RDF) as main plots and four levels of nano DAP foliar spray at 30 and 60 DAS (control, 2, 4, 6 ml l^{-1} of water) as sub plot treatments and were replicated thrice. The result revealed that application of 100% RDF + foliar spray of nano DAP @ 6 ml l^{-1} of water recorded significantly higher no.of leaves plant^{-1}(9.08, 16.36 and 13.74), leaf area plant^{-1} (3288, 4872 and 3691 cm^{-2} plant^{-1}) and leaf area index (2.72, 4.06 and 3.08) at 45, 90 DAS and at harvest, respectively. Yield components cob length (23.52), cob girth (15.99), grain.wt. cob^{-1}(159.59 g cob^{-1}), grain yield (6486 kg ha^{-1}) and stover yield (7899 kg ha^{-1}) and higher nutrient uptake N, P2O5, and K (202.73, 61.69 and 166.98 kg ha^{-1}, respectively). However, it was on par with application of 100 per cent RDF + foliar spray of nano DAP @ 4 ml litre^{-1} of water, 75 per cent RDF + foliar spray of nano DAP @ 6 ml litre $^{-1}$ of water and 75 per cent RDF + foliar spray of nano DAP @ 4 ml litre^{-1}.

Keywords: Maize, RDF, Foliar spray, nano DAP

1. Introduction

Maize (*Zea mays* L.) is one of the important cereal crop next to wheat and rice in the world. In India, it ranks third after rice and wheat. Globally, 1210.24 m t of maize was being produced together by 169 countries from an area of 205.87 m ha with an average productivity of 5.87 t ha^{-1}. United States, China, Brazil, Argentina, Ukraine and India are the leading countries in terms of maize production (Anon., 2021) [1]. In India, it is cultivated over an area of 9.89 m ha with a production of 31.64 m t and the productivity of 3.19 t ha^{-1} (Anon., 2022a) [2]. Broadly, Karnataka, Andhra Pradesh, Uttar Pradesh, Bihar and Madhya Pradesh are the major producers of maize in India. Karnataka ranks first in India and contributes 10 per cent to overall production. In Karnataka, maize is grown over an area of 1.40 m ha with production of 5.22 m t and productivity of 3.28 t ha^{-1} (Anon., 2022b) [3]. In Karnataka, the major maize growing districts are Bellary, Bidar, Vijayapura, Belagavi, Koppal, Raichur, Tumakuru, Chitradurga, parts of Chikkaballapur and Kolar.

Maize is a dual-purpose crop. The grain is used both for human and livestock consumption and stover is solely fed to the livestock. It has high nutritive value as it contains about 7.7-14.6% protein, 0.8-2.32% crude fibre, 69.7-74.5% carbohydrates, 3.2-7.7% fat and ash is about 0.7-1.3% (Anon., 2024a) [4]. Generally, maize is grown during *kharif* season, but it can also be grown during *rabi* and summer seasons because of its photo insensitive nature.

Despite having high yield potential of maize, its productivity is low due to many constraints and one of them is nutrient deficiency in the soil. Although, application of excess quantity of fertilizer will not increase yield of maize, however, maize is a fertilizer responsive crop, but excessive, untimely and unscientific application of fertilizers will have a negative impact on the yield and soil health. Indian agriculture is facing a wide spectrum of challenges in crop production systems such as crop yield stagnation, declining organic matter, multi nutrient deficiencies, low use efficiency of fertilizers, climate change, shrinking of arable land, restricted labour and water availability.

Indian soils are being exhausted heavily, as 30 m t of nutrients removed, while 20 m t added to crops leaving a net deficit of 10 m t every year. Fertilizer response ratio of crops has declined drastically (Bhattacharya *et al*., 2015) [10]. Social and economic issues such as non-availability of labours and escalating cost of cultivation forcing agricultural scientists to evolve technologies that target multifaceted problems of Indian agriculture.

Fertilizers play a pivotal role in agricultural production. Fertilizers have taken axial role with respect to boosting crops yield and nutritional quality especially after the development of fertilizer responsive crop varieties. Among mineral nutrients, nitrogen is the first and foremost nutrient required for crop plants as it is the constituent of chlorophyll and many proteins and enzymes and thus plays a significant role during the vegetative growth of crops. It is estimated that soil application of nitrogen causes greater loss of nitrogen due to denitrification and leaching (Nduwimana *et al*., 2020; Meena *et al*., 2021) [17, 16]. Loss of nitrogen from the soil system not only reduces soil fertility and plant yield but also create adverse impact on environment. Therefore alternate method of application is required.

Along with nitrogen, phosphorous is also an important plant nutrient. Phosphorus is an essential nutrient, both as a part of several key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions in plants. Some specific growth factors associated with phosphorus are stimulated root development, increased stalk and stem strength, improved flower formation and seed production, increased nitrogen N-fixing capacity of legumes, improvements in crop quality, increased resistance to plant diseases, supports development throughout entire life cycle (Patel and Dey, 2022) [19].

It is estimated that phosphorous deficiency can be found in nearly 67 per cent of world land designated for crop production and P use efficiency (PUE) for cereal production in the world is too low, varying between 15 and 30 per cent (Dhillon *et al*., 2017) [13]. Phosphorus can precipitate as minerals of Fe and Al, which decrease the availability of phosphorus for plant growth. On one side requirement of nitrogen and phosphorous by the initial crop is higher and on the other side availability of soil applied N and P to the crop is very low due to losses caused by different processes in the soil.

To address all the challenges ahead, thinking of an alternate technology such as nano technology to precisely detect and deliver correct quantity of nutrients and other inputs required by crops in suitable proportion that promote productivity while ensuring environmental safety.

Nano technology is a field of convergence among life sciences, material science and information technology. Among the advancement in sciences, nanotechnology is being visualized as a rapidly evolving field that has potential to revolutionize agriculture. Nano DAP is a source of nitrogen and phosphorous. This provides essential nutrients to plant for their growth and development. IFFCO nano DAP prepared by nanotechnology, effectively fulfils crop nitrogen and phosphorus requirement when used as seed dressing and foliar spray. It contains about 8 per cent of nitrogen (80,000 ppm) and 16 per cent of phosphorous (1,60,000 ppm). (Anon., 2024b) [5].

2. Materials and Methods

An investigation undertaken on farm during *Kharif*, 2022-23 at Experimental Block, College of Agriculture, Bheemarayanagudi, UAS, Raichur. Karnataka on *Vertisol* having pH 8.32 and EC 0.34dS m^{-1}. The soil was medium in organic carbon content (0.51%) and available P_2O_5 (21.04 kg ha^{-1}), and low in available N (219.91kg ha^{-1}) and high in available K_2O content (369.71kg ha^{-1}). The experimental site was located at a latitude of 16º 15′ North, longitude of 77º 21′ East and an altitude of 389 meters above the mean sea level in Northern Dry Zone of Karnataka (Zone 3). During the year 2022-23, a total rainfall of 431.6 mm was received in 26 rainy days from January 2020 to December 2021 against the average rainfall of 722.9 mm received. The highest rainfall of 146.8 mm was recorded in the month of September followed by July (101.6 mm). The total amount of rainfall documented during cropping period (August-2022 to December-2023) was 188.4 mm.

The experiment was conducted in split plot experimental design with three replications. There were twelve treatment combinations, consisting three RDF levels (M_1 – M_3) in main plots and four stage of application (S_1 – S_4) in sub plots (M_1S_1: 50% RDF + Control (Water spray), M_1S_2: 50% RDF + Nano DAP @ 2 ml l^{-1} of water at 30 and 60 DAS, M_1S_3: 50% RDF + Nano DAP @ 4 ml l^{-1} of water at 30 and 60 DAS, M_1S_4: 50% RDF + Nano DAP @ 6 ml l^{-1} of water at 30 and 60 DAS, M_2S_1: 75% RDF + Control (Water spray), M_2S_2: 75% RDF + Nano DAP @ 2 ml l^{-1} of water at 30 and 60 DAS, M_2S_3: 75% RDF + Nano DAP @ 4 ml l^{-1} of water at 30 and 60 DAS, M_2S_4: 75% RDF + Nano DAP @ 6 ml l^{-1} of water at 30 and 60 DAS, M_3S_1: 100% RDF + Control (Water spray), M_3S_2: 100% RDF + Nano DAP @ 2 ml l^{-1} of water at 30 and 60 DAS, M_3S_3: 100% RDF + Nano DAP @ 4 ml l^{-1} of water at 30 and 60 DAS, M_3S_4: 100% RDF + Nano DAP @ 6 ml l^{-1} of water at 30 and 60 DAS.

The land was ploughed once and harrowed twice to get a fine tilth. Stubbles and weeds were removed from the experimental site and smoothened with wooden plank to prepare fine seed bed before sowing. Later the plots were laid out as per the layout.

The variety MM-9333 was used and Recommended dose of FYM was applied @ 5.0 t ha^{-1} and incorporated well into soil two weeks prior to sowing. Nitrogen (N), phosphorous (P_2O_5) and potassium (K_2O) were applied in the form of urea, di-ammonium phosphate (DAP) and murate of potash (MoP) as per the treatment. Foliar spray of nano DAP @ control (0), 2, 4 and 6 ml l^{-1} of water was sprayed in two times at 30 and 60 DAS. The crop was sown on 19th August 2023 with a spacing of 60 × 20 cm. Crop was given protective irrigation to avoid moisture stress based on needs of the crop. At physiological maturity of the crop, harvesting was done. The cobs were harvested from the standing plants in the net plot area and were sun dried. Then, the fodder was harvested at ground level and sun dried in the field. The sun dried cobs were shelled, cleaned, grain yield and stover yield was recorded after sun drying in the field. Both grain and stover yields were expressed in kg per ha^{-1}.

The yield parameters and other findings were documented from the net plots, and grain yield was converted to kg ha^{-1}. The costs of individual treatment were determined using present market pricing from the current year. To determine profitability, the yield was also calculated for total and profit, as well as the BC ratio. The profit to invested ratio was examined by dividing the amount got during selling obtained yield by the total amount incurred in the cultivation of individual plots. The analysis and interpretation of data were done using the Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967) [18]. The level of significance used in "F" and "T" test was at 5% probability level and wherever "F" test was found significant, the "t" test was performed to estimate critical differences among various treatments.

3. Results and Discussion

3.1 Growth attributes

significantly higher number of leaves per plant at 45, 90 DAS and at harvest were noticed in the treatment receiving 100% RDF with foliar spray of nano DAP @ 6 ml l^{-1} of water (16.36 and 13.74, respectively) of maize as compared to rest of the treatment combinations. However, it was on par with 100% RDF + foliar spray of nano DAP @ 4 ml l^{-1} of water (15.69 and 12.71, respectively), 75% RDF + foliar spray of nano DAP @ 4 ml l^{-1} of water (15.23 and 12.42, respectively) and 75% RDF + foliar application of nano DAP @ 6 ml l^{-1} of water (15.31 and 12.69, respectively) at 90 DAS and at harvest, respectively and is presented in table 1. The combined use of conventional and nano DAP improved nitrogen and phosphorus availability, boosting photosynthesis and growth, which increased plant height and leaf count. These results align with findings by Rajput *et al*. (2022) [20] and Bhargavi and Sundari (2023) [9].

Higher leaf area and leaf area index of maize were recorded by application of 100% RDF with foliar spray of nano DAP @ 6 ml l^{-1} of water (3288, 4872 and 3691 cm^{-2} $plant^{-1}$ and 2.74, 4.06 and 3.08 at 45, 90 DAS and at harvest, respectively). of maize as compared to rest of the treatment combinations. However, it was on par with 100% RDF + foliar spray of nano DAP @ 4 ml l^{-1} of water (3099, 4810 and 3509 cm^2 $plant^{-1}$ and 2.58, 4.01 and 2.97 at 45, 90 DAS and at harvest, respectively), 75% RDF + foliar spray of nano DAP @ 4 ml l^{-1} of water (2988, 4547 and 3463 cm^2 $plant^{-1}$ and 2.49, 3.80 and 2.89 at 45, 90 DAS and at harvest, respectively) and 75% RDF + foliar application of nano DAP @ 6 ml l^{-1} of water (3054, 4798 and 3500 cm^2 $plant^{-1}$ and 2.55, 4.15 and 2.92 at 45, 90 DAS and at harvest, respectively) and is presented in table 1. Adequate supply of nitrogen and phosphorous through conventional and nano fertilizers at right concentration would help in production of more number of leaves due to reduced competition among the plants for nutrients which yielded in higher leaf area. The increased leaf area resulted in increased leaf area index. These findings were in accordance with Mallikarjuna [15].

Table 1: Plant height of maize at different growth stages as influenced by different levels of RDF, nano DAP and their interactions

Treatment	Number of leaves per plant			Leaf area (cm^2 $plant^{-1}$) and leaf area index		
	45 DAS	90 DAS	At harvest	45 DAS	90 DAS	At harvest
Main plot: RDF levels (M)						
M_1: 50%	7.48	12.79	9.86	2370 (1.98)	3812 (3.18)	2517 (2.10)
M_2: 75%	8.07	13.42	10.22	2770 (2.31)	4355 (3.63)	3157 (2.63)
M_3: 100%	8.56	14.71	12.35	2983 (2.49)	4566 (3.81)	3293 (2.74)
S.Em ±	0.12	0.32	0.36	46 (0.03)	53 (0.04)	33 (0.03)
CD @ 5%	0.44	1.27	1.42	182 (0.15)	209 (0.17)	130 (0.11)
Sub plot: Nano DAP levels (S)						
S_1: Control	7.57	12.14	10.05	2399 (2.00)	3727 (3.11)	2624 (2.19)
S_2: 2 ml	7.69	12.58	10.54	2590 (2.16)	4154 (3.46)	2865 (2.39)
S_3: 4 ml	8.38	14.82	11.86	2848 (2.37)	4481 (3.73)	3193 (2.67)
S_4: 6 ml	8.51	15.01	12.12	2994 (2.50)	4616 (3.85)	3275 (2.72)
S.Em ±	0.15	0.24	0.27	62 (0.05)	66 (0.05)	57 (0.04)
CD @ 5%	0.45	0.72	0.80	186 (0.15)	197 (0.16)	170 (0.14)
Interaction effect (M × S)						
M_1S_1	6.99	11.32	9.08	2107 (1.76)	3154 (2.63)	2364 (1.97)
M_1S_2	7.17	12.91	9.97	2275 (1.90)	3642 (3.20)	2466 (2.06)
M_1S_3	7.84	13.36	10.18	2457 (2.05)	4074 (3.40)	2606 (2.17)
M_1S_4	7.93	13.55	10.20	2641 (2.20)	4179 (3.48)	2633 (2.19)
M_2S_1	7.63	11.41	9.41	2423 (2.02)	3684 (3.70)	2681 (2.23)
M_2S_2	7.70	12.67	10.35	2617 (2.18)	4342 (3.65)	2983 (2.49)
M_2S_3	8.42	15.23	12.42	2988 (2.49)	4547 (3.80)	3463 (2.89)
M_2S_4	8.52	15.31	12.69	3054 (2.55)	4798 (4.15)	3500 (2.92)
M_3S_1	8.09	14.05	10.77	2665 (2.22)	4243 (3.62)	2826 (2.36)
M_3S_2	8.20	12.76	12.18	2878 (2.40)	4529 (3.54)	3145 (2.62)
M_3S_3	8.88	15.69	12.71	3099 (2.58)	4810 (4.01)	3509 (2.97)
M_3S_4	9.08	16.36	13.74	3288 (2.74)	4872 (4.06)	3691 (3.08)
S.Em ±	0.26	0.42	0.47	108 (0.09)	114 (0.09)	99 (0.08)
CD @ 5%	0.79	1.24	1.39	322 (0.26)	341 (0.28)	295 (0.24)

( ) – values in bracket indicate leaf area index

3.2 Yield Attributes

Different levels of RDF and nano DAP levels recorded significantly longer cob length (23.52 cm), wider cob girth (15.99 cm) and higher grain weight cob^{-1} (159.9 g cob^{-1}) with 100% RDF + foliar spray of nano DAP @ 6 ml l^{-1} of water, followed by 100% RDF + foliar spray of nano DAP @ 4 ml l^{-1} of water, 75% RDF + foliar spray of nano DAP @ 4 ml $l^{-1}$of water and 75% RDF + foliar spray of nano DAP @ 6 ml $l^{-1}$of water. The interaction effect between different levels of RDF and foliar spray of nano DAP on grain yield, stover yield and harvest index of maize was found significant. Application of 100% RDF with foliar spray of nano DAP @ 6 ml l^{-1} of water registered significantly higher grain yield (6486 kg ha^{-1}), stover yield (7899 kg ha^1) and harvest index of maize (0.46), followed by 100% RDF + foliar spray of nano DAP @ 4 ml $litre^{-1}$ of water, 75% RDF + foliar spray of nano DAP @ 4 ml l^{-1} of water and 75% RDF + foliar application of nano DAP @ 6 ml l^{-1} of water (Table 2). Improvements in yield parameters resulted from enhanced phosphorus availability and efficient photosynthate translocation during tasselling and silking stages. Combining conventional DAP with nano DAP at sowing and foliar spraying during reproduction provided timely nitrogen and phosphorus, increasing photosynthetic activity and photosynthate production. This led to longer cob lengths, wider girth, and higher grain weights, consistent with findings by Alzreejawi and Al-Juthery (2020) [6], Ajithkumar *et al*. (2021) [7], and Hena *et al*. (2022) [14].

Table 2: Number of cobs plant-1, cob length, cob girth, grain weight cob-1, test weight, Grain yield, Stover yield and HI of maize at harvest as influenced by different levels of RDF, nano DAP and their interactions

Treatments	Cob length (cm)	Cob girth (cm)	Grain. wt cob^{-1}(g)	Test weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	HI
Main plot: RDF levels (M)							
M_1: 50%	17.77	12.79	119.94	17.83	4496	6133	0.42
M_2: 75%	19.87	13.64	133.91	20.53	5522	6741	0.45
M_3: 100%	21.81	14.65	148.85	23.61	6067	7184	0.46
S.Em ±	0.30	0.23	3.65	0.66	113	111	0.01
CD @ 5%	1.20	0.93	14.36	2.62	446	438	NS
Sub plot: Nano DAP levels (S)							
S_1: Control	17.09	12.42	122.40	18.45	4765	6206	0.43
S_2: 2 ml	19.12	13.19	127.05	18.93	5157	6463	0.44
S_3: 4 ml	21.16	14.39	142.04	22.22	5684	6950	0.45
S_4: 6 ml	21.89	14.89	145.44	23.02	5840	7124	0.45
S.Em ±	0.33	0.26	2.53	0.70	93	125	0.01
CD @ 5%	0.98	0.78	7.54	2.08	277	373	NS
Interaction effect (M × S)							
M_1S_1	14.83	11.71	110.42	16.26	4180	6074	0.41
M_1S_2	17.52	12.52	117.90	16.60	4447	6118	0.42
M_1S_3	19.34	12.66	125.60	19.04	4468	6154	0.42
M_1S_4	19.37	13.49	125.84	19.42	4890	6186	0.44
M_2S_1	16.32	12.48	115.03	18.53	4716	6155	0.43
M_2S_2	18.40	13.25	119.41	18.87	5117	6261	0.45
M_2S_3	21.97	14.79	150.33	22.30	6109	7260	0.46
M_2S_4	22.79	15.20	150.89	22.40	6144	7289	0.46
M_3S_1	20.10	12.90	141.75	20.55	5400	6389	0.46
M_3S_2	21.44	13.83	143.85	21.33	5907	7009	0.46
M_3S_3	22.18	15.86	150.20	25.31	6475	7438	0.47
M_3S_4	23.52	15.99	159.59	27.26	6486	7899	0.46
S.Em ±	0.57	0.45	4.39	1.21	161	217	0.02
CD @5%	1.70	1.35	13.06	NS	481	646	NS

3.3 Nutrient uptake and available nutrients in soil at harvest

The interaction effect was found significant between the different levels of RDF and nano DAP on total nitrogen, phosphorous and potassium uptake. Significantly higher nitrogen, phosphorous and potassium uptake (202.73, 61.69 and 166.98 kg ha^{-1}, respectively) was recorded in treatment that received 100% RDF + foliar spray of nano DAP @ 6 ml l^{-1}of water, followed by 100% RDF + foliar spray of nano DAP @ 4 ml l^{-1} of water, 75% RDF + foliar spray of nano DAP @ 4 ml l^{-1} of water and 75% RDF + foliar spray of nano DAP @ 6 ml 1^{-1} of water. The combination of conventional fertilizer and foliar spray of nano DAP provide the plant with the optimal amount of nutrients at the right time. The conventional fertilizer can provide the plant with the nutrients it needs for early growth, while the foliar spray of nano DAP can provide the plant with the nutrients it needs for later growth. The results are in accordance with the finding of Babubhai (2018) [8] in maize and Deo *et al.* (2022) [12] in rice.

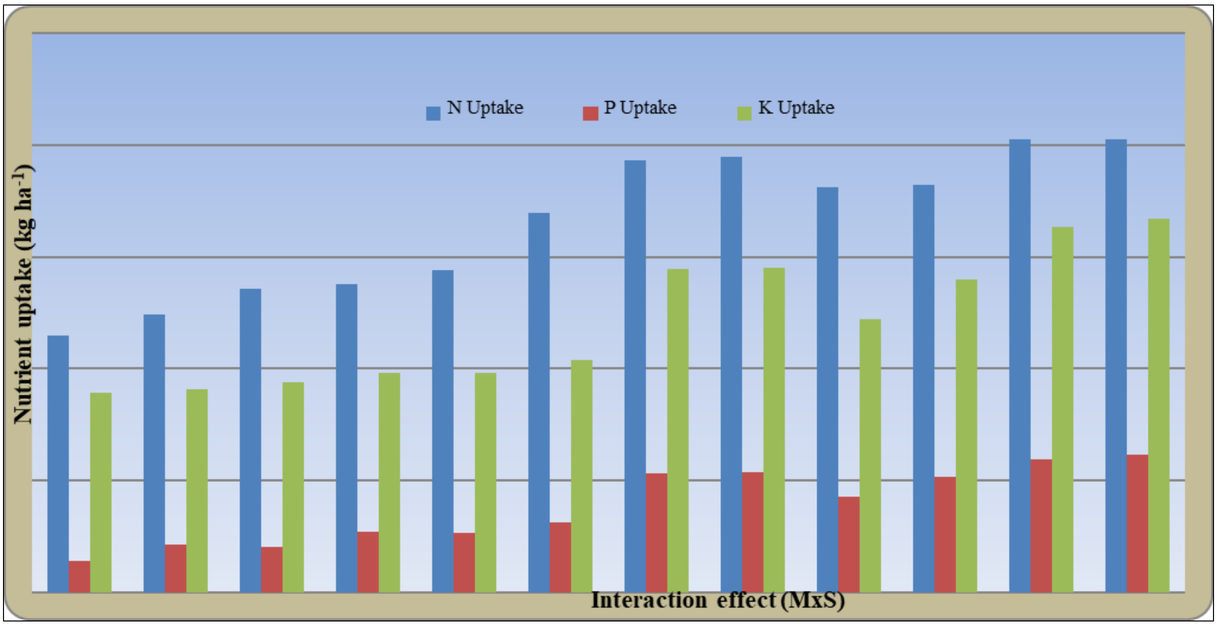

Fig. 1: Uptake of nitrogen, phosphorous, potassium uptake in maize at harvest as influenced by different levels of RDF, nano DAP and their interactions

4. Conclusion
Application of 100% RDF in combination with foliar spray of nano DAP @ 6 ml l^{-1} resulted in higher growth and yield components and yield of maize followed by 100% RDF + foliar spray of nano DAP @ 4 ml l^{-1}, 75% RDF +foliar spray of nano DAP @ 4 ml l^{-1} of water and 75% RDF + foliar spray of nano DAP @ 6 ml^{-1} of water over other treatments.Thus, the study establishes the fact that 25% of recommended dose of fertilizer can be saved by using nano DAP fertilizer as foliar spray for obtaining higher yield and economic returns of maize.

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