

Influence of conservation agriculture-based management practices on phenology, productivity, profitability and soil health in banana (*Musa* spp.) + elephant foot yam (*Amorphophallus paeoniifolius*) system

K. REMYA¹ AND G. SUJA²

ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala 695 017

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ABSTRACT

A field experiment was conducted during 2014–16 at Thiruvananthapuram, Kerala to develop sustainable intensification package for 'Gajendra' elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] in 'Robusta' banana (*Musa* spp.)-based system using resource conservation practices. Five treatments, comprising conservation organic (T₁), conservation chemical (T₂), conventional chemical (T₃), conventional (package of practices (PoP)) as control (T₄) and organic management + conventional tillage (T₅), were replicated 4 times in randomized block design. Growth, yield, soil physico-chemical-biological properties, system productivity and profitability of different treatments were studied. Combined analysis of yield indicated that the average corm yield of elephant foot yam was not significantly influenced by treatments, but conservation chemical practice resulted in 13.55% higher yield than conventional POP. Conservation chemical management resulted in the highest bunch yield (44.76 t/ha) of banana, which was on par with all other practices (39–40 t/ha), except organic package (29.48 t/ha). Banana yield under conservation chemical management was 12.97% higher than the conventional PoP. In both the years, higher pH was noticed under conservation organic management, which was on a par with organic package. The conservation chemical treatment enhanced the available K content, which was at par with PoP and conservation organic at the end of 2 years. The exchangeable Ca, Mg, available Mn and Zn status were significantly higher and at par under conservation organic and conventional organic treatments. All the other soil parameters, bulk density, particle density, water-holding capacity, porosity, organic C, EC, available N, P, CEC, population of bacteria, fungi and actinomycetes, activity of soil enzymes, viz. dehydrogenase, acid phosphatase and urease were unaffected by the different management practices. In terms of banana + elephant foot yam system, the conservation chemical management proved to be the most productive (+13% over PoP) and profitable (+32%) as revealed from the highest total tuber-equivalent yield (45.34 t/ha), production efficiency (151.13 kg/ha/day), gross income (₹1,360,170/ha), net income (₹866,421/ha) and benefit: cost ratio (2.75).

Key word : Banana, Conservation agriculture, Economics, Elephant foot yam, Production efficiency, Soil quality, Tuber equivalent yield

Currently Indian agriculture is facing the triple challenges of resource fatigue, decelerating productivity growth and management yield gaps. Agriculture, forestry and land-use change account for 30% of greenhouse gas emissions. The challenges are further exacerbated with the projected climate change effects, sharp rise in the price of food and energy, depleting water resources, land degradation, desertification and loss of biodiversity. The chal-

lenges will be even more threatening as the Indian population in 2050 will be 1,750 million, per capita land availability will be 0.089 ha with projected fresh water supply of merely 1,190 m³/year.

This warrants a paradigm shift to intensification of agricultural systems for higher production but with efficient resource use, while sustaining natural resource base and reducing environmental footprints. Conservation agriculture (CA) is a sustainable option to adapt to climate change and reduce the water foot print based on the 3 core inter-linked principles of minimum soil disturbance, permanent soil cover (by crop residues, mulching or cover crops) and crop diversification. Several studies conducted across the production systems under varied ecologies of

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¹Corresponding author's Email: sujagin@yahoo.com

¹Ph.D. Scholar, ²Principal Scientist (Agronomy), Division of Crop Production, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala 695 017

India revealed that CA-based crop-management technologies had potential benefits on resource conservation, use efficiency of external inputs, yield optimization/ enhancement (Sharma *et al.*, 2012; Jat *et al.*, 2013; 2014; Sidhu *et al.*, 2015; Yadvinder-Singh *et al.*, 2015), soil-health improvement (Jat *et al.*, 2013; Singh *et al.*, 2016) and adaptation and mitigation to climate change (Jat *et al.*, 2016).

Elephant foot yam is an important tropical tuber crop popular as a nutritive vegetable and a food security crop, besides having medicinal values. Banana (var. Robusta) is an important cash crop, whose fully ripe fruit serves as a dessert delicacy. Intercropping elephant foot yam in banana is a profitable enterprise and commonly practiced in over 45,000 ha in the major elephant foot yam-growing states of Kerala, Andhra Pradesh, West Bengal, Bihar, Odisha, Jharkhand, Chhattisgarh, Telangana, Uttar Pradesh etc. Presently information on CA in tropical tuber crops, which are mostly components of promising cropping systems, is lacking. Hence the objectives were to develop environment-friendly resource-conserving technologies for elephant foot yam in banana-based system and to assess the impact of conservation agriculture on growth, yield, soil properties, system productivity and economics of banana + elephant foot yam system.

MATERIALS AND METHODS

The field experiment was conducted during 2014–2016 at ICAR-Central Tuber Crops Research Institute, (8°29'N, 76°57'E, 52 m altitude) Thiruvananthapuram, Kerala, India. The total annual rainfall received during April 2014–March 2015 and April 2015–March 2016 was 1,035.4 mm and 1,735.4 mm, maximum and minimum temperatures were 31.82°C and 24.04°C in the first year and 32.12°C and 23.73°C in the second year, and relative humidity was 81.46% and 83.53% in the first and second years respectively.

The experimental soil was clayey in texture with acidic pH (5.38), high organic C (0.85%), low available N (69.38 kg/ha), higher available P (54.87 kg/ha) and higher available K (292.20 kg/ha). The experiment was laid out in randomized block design with 5 treatments, viz., conservation organic (T₁), conservation chemical (T₂), conventional chemical (T₃), conventional [package of practices (PoP)] as control (T₄) and organic management + conventional tillage (T₅), replicated 4 times. Description of treatments and nutrient-management options in the various treatments are given in Table 1 and 2. Elephant foot yam (var. 'Gajendra') was intercropped in banana (var. 'Robusta'). The gross plot size was 9.6 m × 7.2 m, accommodating 16 banana at a spacing of 2.4 m × 1.8 m and 60 elephant foot yam plants at a spacing of 90 cm × 90 cm. The net plot size was 4.8 m × 3.6 m accommodating 4 banana and 32

elephant foot yam. Banana was planted in pits of 50 cm³ and elephant foot yam in 60 cm × 60 cm × 45 cm sized pits.

The growth characters of elephant foot yam and banana at various stages were measured. Yield and yield attributes of elephant foot yam and banana were recorded. The yield data were combined over years.

The soil samples were collected at the end of the experiments in each year and analyzed for pH, organic C, major, secondary and micro-nutrients by standard procedures. The physical properties of the soil and microbial count of bacteria, fungi and actinomycetes were done by standard methods. Activities of soil enzymes, dehydrogenase, acid phosphatase (phosphomonoesterase) and urease were also estimated by standard procedures.

Total cost of cultivation and gross returns were calculated from the average input cost and average market price of the produce during the period of investigation. The net return (₹/ha) from the different treatments for each year was worked out by subtracting the gross cost from gross income and the average results are reported. Benefit: cost ratio (B : C ratio) of the different treatments for each year was computed by dividing the gross income by the gross cost and the average values are reported. The total tuber-equivalent yield and production efficiency of the various treatments were worked out for the 2 years as per Nedunchezhiyan (2007) and mean trend are reported and discussed. The analysis of variance of data was done using SAS (2010) by applying analysis of variance technique (ANOVA) for randomized block design. Wherever significant difference among treatments was detected through ANOVA, critical differences (CD) are provided for effective comparison of means.

RESULTS AND DISCUSSION

Growth dynamics

Significant effect of management practices on pseudostem height of elephant foot yam was observed during the initial stages i.e. 3 or 4 months after planting (MAP) in both the years (Table 3). In the first year, at 3 MAP, pseudostem height in conventional chemical was higher and at par with the existing conventional practice (PoP) on account of better soil environment for nutrient availability owing to conventional tillage in these treatments, as also observed by Yaduvanshi and Sharma (2008). In the second year, at 3 and 4 MAP, conservation chemical management resulted in taller plants, which was at par with all the other treatments, except conservation organic at 3 MAP and conventional chemical at 4 MAP. The better growth in conservation chemical may be attributed to the effect of mulching combined with greater weed control due to application of herbicides. At the remaining

stages, the treatments exerted similar effects on height. There was no significant variation in stem girth in the first year. But in the second year, at the mid-growth phase (5 MAP), stem girth was significantly higher in the conventional chemical treatment, which was at par with existing organic package and existing conventional practice (PoP). This is probably owing to better soil condition and reduction in crop-weed competition under conventional tillage in all these treatments. Canopy spread was not significantly influenced by the various treatments in the first

year. But in the second year, at 4 MAP, existing organic package resulted in greater canopy spread, which was at par with all the treatments, except conservation organic.

Significant difference was not observed at various stages during the period of experimentation on the height of pseudostem, girth of pseudostem and leaf production in banana.

Yield

The productivity of elephant foot yam and banana was

Table 1. Description of treatments

| Treatment | Tillage + nutrient management + weed-management practices |
|--|--|
| T ₁ , Conservation organic | Conservation practices such as minimum tillage [#] , crop residue retention, green manuring, + non-chemical method of weed management (cultural (mulching, green manuring) and mechanical (hand-weeding)) and nutrient management by organic mode |
| T ₂ , Conservation chemical | Conservation practices such as minimum tillage, crop-residue retention, green manuring + chemical method of weed-management [§] and need-based application of manures and fertilizers based on soil testing* |
| T ₃ , Conventional chemical | Conventional tillage**, mulching + chemical method of weed-management* and need-based application of manures and fertilizers based on soil testing |
| T ₄ , Conventional (PoP) (Control) | Existing conventional practice: conventional tillage, mulching + hand-weeding and FYM @ 25 t/ha and N, P and K @ 100, 50, 150 kg/ha |
| T ₅ , Organic management + conventional tillage | Conventional tillage, mulching + hand weeding and organic method of nutrient management |

[§]Pre-emergence application of Oxyfluorfen @ 0.2 kg ai/ha within 6 days planting; *based on Aiyer and Nair (1985) in the first year 90% N, 0 P and 60% K; Second year 90% N, 0 P and 83% K of the PoP recommendation of NPK to both the crops; [#]minimum tillage: 1 ploughing, digging for pit formation alone, 1 weeding; **conventional tillage: 2 ploughings, digging of entire area before pit preparation, 2 weedings
Crop residue addition in T₁ and T₂ @ 7 t/ha

Fresh biomass from green-manure cowpea in T₁, T₂ and T₅ were 7.78, 1.55, 8.57 t/ha in the first year and 7.47, 2.83 and 5.59 t/ha in the second year

Table 2. Description of nutrient-management options

| Treatment | Nutrient-management mode | Banana | Elephant foot yam |
|---|--------------------------------|---|---|
| Conservation organic (T ₁) | Organic | FYM @ 10 kg/plant at planting + organic manures to supply NPK @ 160:160:320 g/plant/year in 2 equal split doses at 2 MAP and 4 MAP | Seed treatment in FYM+ neem cake + <i>Trichoderma</i> slurry. Application of FYM @ 36 t/ha, <i>in-situ</i> green manuring, neem cake @ 1 t/ha, ash @ 3 t/ha |
| Conservation chemical (T ₂) | Chemical based on soil testing | FYM @ 10 kg/plant; NPK @ 144:0:200 g/plant (first year) and 144:0:255 g/plant (second year) | FYM @ 25 t/ha; NPK @ 90:0:90 kg/ha (first year) & 90:0:120 kg/ha (second year) |
| Conventional chemical (T ₃) | Chemical based on soil testing | FYM @ 10 kg/plant; NPK @ 144:0:200 g/plant (first year) and 144:0:255 g/plant (second year) | FYM @ 25 t/ha; NPK @ 90:0:90 kg/ha (first year) and 90:0:120 kg/ha (second year) |
| Conventional (PoP) (Control) (T ₄) | Chemical as in PoP | FYM @ 10 kg/plant at planting + NPK @ 160:160:320 g/plant/year in 2 equal split doses at 2 MAP and 4 MAP | FYM @ 25 t/ha and NPK @ 100:50:150 kg/ha; twice at 45 DAP and 1 month after the first application, i.e. 75 DAP |
| Organic management + conventional tillage (T ₅) | Organic | FYM @ 10 kg/plant at planting + organic manures to supply NPK @ 160:160:320 g/plant /year in 2 equal split doses at 2 MAP and 4 MAP | Seed treatment in FYM+ neem cake + <i>Trichoderma</i> slurry. Application of FYM @ 36 t/ha, <i>in-situ</i> green manuring, neem cake @ 1 t/ha, ash @ 3 t/ha |

the years (Table 5). In both the years, higher pH was noticed under conservation organic treatment, which was at par with organic package. At the end of the period of experimentation, the pH was increased by 0.65 unit in the conservation organic treatment over the existing PoP. It is to be noted that the pH in the conservation organic treatment was slightly higher (+0.16 unit) over the initial pH of the experimental site (5.42), whereas it was reduced by 0.41 unit in plots where existing PoP (5.34) was practiced. This is mainly because of decrease in the activity of exchangeable Al^{3+} ions in soil solution due to chelation by organic molecules, due to the non-use of urea and extra cation supply due to green manure cowpea and crop residue retention in conservation organic treatment. Moreover, the Ca content in farmyard manure (0.08%), green manure (0.41%), neem cake (1.75%) and ash (15%) might have contributed to self-liming effect of the soil in conservation organic plots. Similar increase in pH was reported under organic management in elephant foot yam (Suja *et al.*, 2012), yams (Suja and Sreekumar, 2014) and taro (Suja *et al.*, 2017).

The organic C, available N and P status were not significantly influenced by the treatments (Table 5). The organic C content was higher under conservation treatments in the 2 years, 9.36% and 16.95%, respectively, over existing PoP (Table 5), owing to large amounts of crop residues left on the soil surface and slow rate in the breakdown of organic matter under conservation tillage practices (Lal *et*

al., 2004). Similar observation of higher soil organic C was observed by Kachroo *et al.* (2017) in strip till-drill and zero till-drill in wheat and Parihar *et al.* (2016) in CA-based sustainable intensification in maize systems. The organic C content was the lowest under existing PoP in the first year and organic package during the second year. The available N content was higher in either of the PoP treatments. The available P status was higher under conservation chemical and conservation organic treatments during the first and second years respectively. Significant difference was observed in the status of available K at the termination of the experiment. The conservation chemical treatment enhanced the available K content, being at par with PoP and conservation organic in the second year. This is certainly owing to addition of K from green manure cowpea. The K mining effect from the sub surface layers by the extensive root system of green manure crop of cowpea, organic acid dissolution of the rather inaccessible K minerals in the soil during green-manure decomposition, also might have contributed to higher content of available K in the conservation chemical plots, where green manuring and crop-residue retention was advocated. Sharma *et al.* (2015) also observed higher available P and K in CA-based sustainable intensification in cereal-based systems in a reclaimed sodic soil at the Central Soil Salinity Research Institute (CSSRI), Karnal, Haryana.

Electrical conductivity (EC) and cation-exchange capacity (CEC) were not significantly influenced by the

Table 5. Effect of resource conservation practices on major chemical properties of the soil under banana + elephant foot yam system

| Treatment | pH | | Organic C (%) | | Available N (kg/ha) | | Available P (kg/ha) | | Available K (kg/ha) | |
|------------------------------|---------|---------|---------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| | 2014–15 | 2015–16 | 2014–15 | 2015–16 | 2014–15 | 2015–16 | 2014–15 | 2015–16 | 2014–15 | 2015–16 |
| Conservation organic | 5.22 | 5.58 | 1.00 | 1.48 | 62.52 | 191.47 | 38.41 | 137.95 | 178.25 | 166.71 |
| Conservation chemical | 4.81 | 4.84 | 1.04 | 1.28 | 79.77 | 149.36 | 42.94 | 85.64 | 174.66 | 174.94 |
| Conventional chemical | 4.88 | 4.81 | 0.88 | 1.16 | 88.83 | 175.39 | 33.43 | 81.99 | 148.79 | 129.30 |
| Conventional (POP) (Control) | 4.81 | 4.93 | 0.94 | 1.18 | 73.30 | 230.27 | 23.26 | 86.08 | 161.50 | 168.06 |
| Organic package | 5.13 | 5.38 | 0.97 | 0.89 | 49.63 | 188.64 | 20.05 | 101.34 | 149.91 | 99.74 |
| SEM± | 0.08 | 0.14 | 0.06 | 0.14 | 13.52 | 20.93 | 7.44 | 13.79 | 13.01 | 13.22 |
| CD (P=0.05) | 0.24 | 0.42 | NS | NS | NS | NS | NS | NS | NS | 40.75 |

Table 6. The secondary and micro-nutrient status of the soil as affected by conservation vs conventional treatment

| Treatment | Exchangeable Ca (cmol/kg) | | Exchangeable Mg (cmol/kg) | | Available Mn (ppm) | | Available Zn (ppm) | |
|------------------------------|---------------------------|---------|---------------------------|---------|--------------------|---------|--------------------|---------|
| | 2014–15 | 2015–16 | 2014–15 | 2015–16 | 2014–15 | 2015–16 | 2014–15 | 2015–16 |
| Conservation organic | 2.14 | 3.57 | 0.99 | 2.28 | 19.75 | 20.00 | 3.85 | 5.13 |
| Conservation chemical | 1.28 | 2.67 | 0.66 | 1.79 | 15.90 | 16.91 | 4.27 | 3.63 |
| Conventional chemical | 1.43 | 2.54 | 1.04 | 1.49 | 15.57 | 15.80 | 3.55 | 3.34 |
| Conventional (PoP) (Control) | 1.47 | 2.63 | 0.78 | 1.62 | 16.84 | 15.53 | 3.07 | 3.17 |
| Organic package | 1.39 | 3.05 | 0.72 | 2.02 | 18.14 | 22.63 | 3.13 | 4.52 |
| SEM± | 0.29 | 0.19 | 0.19 | 0.10 | 1.60 | 1.98 | 0.63 | 0.34 |
| CD (P=0.05) | NS | 0.593 | NS | 0.302 | NS | 6.112 | NS | 1.057 |

management options. The exchangeable Ca, Mg, available Mn and Zn status were significantly influenced by the treatments by the end of the second year (Table 6). The exchangeable Ca and Mg status were found significantly higher under conservation organic and existing organic treatments. The exchangeable Ca was increased by 35.74% and 15.96%, respectively, in the conservation organic and existing organic package over the PoP. The exchangeable Mg was increased by 40.74% and 24.69%, respectively in the conservation organic and existing organic package over PoP. Existing organic package resulted in higher Mn and Zn contents in the second year, which was at par with conservation (both organic and chemical) practices. This is solely owing to the substantial contribution of secondary and micronutrients, especially Ca, Mg, Fe, Mn, Zn and Cu contained in the organic manures, viz. FYM, green-manure cowpea, crop residue and ash under organic management in these treatments, while the chemical fertilizers are only sources of major nutrients.

Biological properties: Microbial population remained statistically unaffected due to treatments during both the years (Table 7). However, in the first and second years, the bacterial count was the highest in the existing organic package and conservation organic packages, the fungal population in the existing PoP and conservation organic and the actinomycetes count was maximum in conventional chemical and conservation chemical. To some extent in the present study, the microbial counts were favoured in conservation treatments owing to addition of sufficient biomass through crop residues and green manure in accordance to the report of Sharma *et al.* (2015) in CA-based maize–wheat–mungbean system.

Soil enzyme activity was not significantly affected by the treatments during both the years. However, in the first year, dehydrogenase activity was higher under conservation treatments and in the second year, existing organic package resulted in higher activity of the enzyme. In both the years, acid phosphatase activity was higher in conventional chemical treatments. Urease activity was similar in the different treatments.

System productivity and profitability
The conservation chemical treatment proved to be the most profitable as revealed from the highest gross income, net income and benefit: cost ratio (2.75), closely followed by, but with almost similar returns in the conventional chemical treatment (Table 8). The net returns were enhanced by 32% over the existing conventional PoP owing to conservation chemical practice in banana + elephant foot yam system, a common and widely adopted cropping system in south India. This was owing to the higher productivity (+13%) and lower cost of production (–9%) for land preparation and weed control, especially in the conservation chemical treatment. Our results confirm the find-

Table 7. Microbial population of soil as affected by resource conservation practices

| Treatment | Bacteria (cfu/g soil) | | Fungi (cfu/g soil) | | Actinomycetes (cfu/g soil) | |
|------------------------------|-----------------------|----------------------|-----------------------|----------------------|----------------------------|----------------------|
| | 2014–15 | 2015–16 | 2014–15 | 2015–16 | 2014–15 | 2015–16 |
| Conservation organic | 12.75×10 ⁶ | 6.17×10 ⁶ | 2.66×10 ⁴ | 7.17×10 ⁴ | 2.00×10 ⁵ | 3.42×10 ⁵ |
| Conservation chemical | 7.83×10 ⁶ | 3.67×10 ⁶ | 12.58×10 ⁴ | 6.84×10 ⁴ | 3.25×10 ⁵ | 4.09×10 ⁵ |
| Conventional chemical | 6.41×10 ⁶ | 5.42×10 ⁶ | 10.41×10 ⁴ | 7.09×10 ⁴ | 3.83×10 ⁵ | 3.75×10 ⁵ |
| Conventional (POP) (Control) | 5.33×10 ⁶ | 3.00×10 ⁶ | 55.00×10 ⁴ | 5.00×10 ⁴ | 1.50×10 ⁵ | 3.92×10 ⁵ |
| Organic package | 32.67×10 ⁶ | 3.67×10 ⁶ | 32.50×10 ⁴ | 3.50×10 ⁴ | 2.08×10 ⁵ | 2.75×10 ⁵ |
| SEm± | 9.87×10 ⁶ | 1.40×10 ⁶ | 10.62×10 ⁴ | 1.40×10 ⁴ | 0.85×10 ⁵ | 0.74×10 ⁵ |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

Table 8. System productivity and profitability of banana + elephant foot yam system as affected by conservation versus conventional treatments (pooled mean of 2 years)

| Treatment | Yield (t/ha) | | Tuber equivalent yield (t/ha) | Production efficiency (kg/ha/day) | Gross income (₹/ha) | Gross cost (₹/ha) | Net income (₹/ha) | Benefit: cost ratio |
|------------------------------|--------------|-------------------|-------------------------------|-----------------------------------|---------------------|-------------------|-------------------|---------------------|
| | Banana | Elephant foot yam | | | | | | |
| Conservation organic | 38.83 | 20.12 | 39.54 | 131.79 | 11,86,055 | 655,500 | 530,555 | 1.81 |
| Conservation chemical | 44.76 | 22.96 | 45.34 | 151.13 | 13,60,170 | 493,749 | 866,421 | 2.75 |
| Conventional chemical | 38.86 | 23.90 | 43.33 | 144.45 | 13,00,018 | 509,749 | 790,269 | 2.55 |
| Conventional (PoP) (Control) | 39.62 | 20.22 | 40.03 | 133.43 | 12,00,816 | 542,789 | 658,027 | 2.21 |
| Organic package | 29.48 | 20.24 | 34.98 | 116.62 | 10,49,568 | 665,500 | 384,068 | 1.58 |
| SEm± | 3.80 | 1.32 | 1.66 | 5.55 | 49,943 | | 49,943 | 0.08 |
| CD (P=0.05) | 8.18 | NS | 4.85 | 16.20 | 145,753 | – | 145,753 | 0.26 |

ings of Tran Quoc *et al.* (2008) and Leinhard *et al.* (2014), who reported that significant increase in economic returns to the extent of 20 to 50% in maize–rice bean conservation agriculture system was owing to win-win combination of reduced production costs × increased yields. The system productivity was also highest for conservation chemical and conventional chemical treatments, as indicated by the highest tuber equivalent yield (45.34 t/ha and 43.33 t/ha) and production efficiency (151.13 and 144.45 kg/ha/day). Similar results of higher system productivity under minimum tillage + mulching was also reported by Prasad *et al.* (2014) in soybean-based system.

It can be concluded that conservation agriculture with chemical management package is a sustainable option in elephant foot yam + banana system owing to its productive-cum-profitable-cum-soil building nature. The resource-conservation practices enhanced yield by 13%, reduced production costs by 9%, profit by 32%, improved the pH, available K, Ca, Mg, Mn and Zn status.

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