Comparative Effects of Poultry Waste, Biochar and Blended Biochar on the Yield of Okra (*Abelmoschus esculentus*)

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Abstract:- **Various soil activities that lead to soil degradation have brought about the use of biochar as an amendment to rebuild soil health, improve crop yields, increase soil water storage, and restore soils affected by these activities particularly when blended with poultry manure.Poultry manure has been proven to be a good organic fertilizer for the growth and yield of plants.**

Pot experiments were conducted to assess the growth rate of okra in response to poultry waste, biochar and blended biochar addition to soil. The treatments were arranged in completely randomized design with 13 treatments comprising 10 g kg^{-1}, 30 g kg^{-1}, 50 g kg^{-1}and 70 g kg^{-1} addition of poultry waste, biochar, blended biochar to soil and a control. There were 5 replications in each of the treatments except the control and the parameters assessed during the experiment were: plant height (cm), leaf area (cm^2), stem diameter (mm) and leaf count.

The observations recorded on the growth parameters on the 35th day showed that poultry wastes at 30g kg^{-1} on topsoil (T2) performed best in plant height with the mean of 32.58 cm, mean stem diameter of 51.20 mm and mean leaf area of 47.50cm^2 while blended biochar at 30g kg^{-1} performed best in leaf production. However, it was observed that okra plants in soil treated with blended biochar at different rates started showing rapid growth in other parameters like stem height, stem diameter and leaf area from 30th day.

Bud production was also assessed on the 35th day of the experiment and it was observed that soil blended biochar at 50g kg^{-1} had the best bud production which indicated high yield of okra fruit. Among the treatments, blended biochar at 50g kg^{-1} of topsoil has the highest number of buds. Thus, it is proposed that for the soil having similar physico-chemical properties, the same rate of blended biochar should be used for high yield production of okra. These results provide an avenue for soil management systems with blended biochar as an amendment for horticultural crops. However, long time verification in the field is suggested for specific recommendations.

Keywords: **Biochar, Blended Biochar, Poultry Manure, Okra, Bud Production**

I. INTRODUCTION

Soil degradation is the most serious biophysical constraint limiting agricultural productivity in many parts of the word, particularly in the tropics. The long term benefit of assigning more land to agriculture will not offset the negative environmental impacts of land degradation in the future, rather, a more promising approach to ensuring food security is to increase yield from currently cultivated land where productivity is low (Ehui and Pender, 2005). The adverse effects of such soil degradation is difficult to handle, especially if severe. Hence, early intervention in the rehabilitation of degraded soils is very important in achieving quick positive results and reversing the trend of degradation. Hence, there is the need to search for organic amendments which could be utilized as fertilizer. Such amendments should be readily available, environmentally friendly and cheap. Integrating such amendments with one another might be the key to attaining good yield. The release of atmospheric carbon dioxide (CO_2) at nearly 400 ppm which continues to rise due to human activities, with consequences to global climate, human health (Lafferty, 2009), agriculture (Auffhammer et al., 2012), and biodiversity (Bakkenes et al., 2002) is classified as one of the soil degrading agents.

Poultry waste is a type of organic manure used for the purpose of soil amendment. Areas of intense poultry production experience over fertilization of pasture land with poultry manure and as a result, it is suspected in groundwater and surface water problems due to excess nutrients run-off or leach into groundwater supplies. To obtain maximum economic value of plant nutrients in poultry manure and to protect our water supplies from excessive nutrient runoff or leaching, poultry manure should be applied to match nutrient needs of crops. Biochar application to the soil has been found to be another way of reducing the amount of organic manure applied to the soil for improving the soil for agricultural productivity.

Biochar is a carbon-rich product produced from the pyrolysis of waste biomass under a little oxygen condition at relatively low temperature. Biochar can be produced from waste biomass in which the following are included; hard woods, rice husks, tea waste, cotton stalks, wheat straw, animal litters, wood shaven and saw dusts. When used as a soil amendment, biochar has an extremely porous carbon structure which allows for effective water and nutrient storage, as well as providing a habitat for high quantities of soil microbes. Biochar provides a lot of benefits, including increasing nutrient availability, increasing soil water retention, improving crop yield, and sequestering carbon for hundreds to thousands of years. Biochar can be activated by the addition of wastewater or organic manure containing high contents of nitrogen and phosphorous which presents a potential fertility and resource recycling opportunity.

Okra (*Abelmoschusesculentus)* is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. Okra is a multipurpose crop due to its various uses of the fresh leaves, buds, flowers, pods, stems and seeds. Okra is an important vegetable crop with a diverse array of nutritional quality and potential health benefits. It is taken as an experimental plant for this study because of its relevance in most Nigerian homes and its medicinal uses. Its period of planting to fruiting does not exceed two months. Despite the hazardous effects of inorganic fertilizers made known to the farmer, they are reluctant in using organic manure and prefer the inorganic fertilizer utilization because of its quick action on plants despite that it is costly and scarce.

The objectives are to:

i. char wood waste such as sawdust and wood shavings to produce a biochar.
ii. analyze topsoil, poultry waste and biochar so as to have the knowledge of the initial nutrient content.
iii. compare the effects of poultry waste, biochar, and modified biochar with poultry waste on the growth of Okra.

II. MATERIALS AND METHOD

The experiment was carried out at the nursery garden of the Forestry Research Institute of Nigeria (FRIN), located within the Government Reserve Area (GRA), Jericho, Ibadan North – West Local Government Area, Oyo State. The area lies between latitude 7^0 26N and longitude 3^0 51E. The climate pattern is tropically dominated by annual rainfall ranges from 1,300 mm to 1,500 mm, an average relative humidity of about 65 % and average temperature of 26^0 C. The dry season usually commence from November to March while the raining season is usually April to October.The equipment and tools used for sample collection, preparation and testing in this study are: Electronic digital venire caliper, Hand gloves, Wheelbarrow, Polythene pots, 0.5 mm gauge sieve, Weighing scale, Sensitive scale, Watering can, Hand trowel, Ruler, Meter rule, Shovel, and record book.

The preparation of biochar requiredsawdust, bioreactor or kiln, shovel and sacks. The sawdust used as feedstock was collected using shovel and sacks at the carpentry workshop of the Forestry Research Institute of Nigeria (FRIN). The saw dust was air-dried for one week before it was taken to the biotechnology unit of the same research institute where pyrolysis of the sawdust took place. The slow pyrolysis took place at the temperature range of 500 ^oC for 120 mins. using a temperature controlled kiln. The sawdust used was a waste generated from gmelina tree (*gmelinaarborea*) after being worked on.

The collection and preparation of poultry waste require the following basic materials: spade, wheelbarrow and sacks.The poultry manure used for this study was collected using spade and wheelbarrow at the poultry pen of the Federal College of Forestry, Idi ishin, Jericho, Ibadan. It was spread on sacks for air-drying for two weeks in order to reduce the amount of ammonia as a result of the reducing pH level(Ghaly and Alhattab, 2013).The quantity of biochar produced for the study was 3.6 kg from which 1.2 kg was measured out for the blending operation. The biochar was blended or activated with the same rate of poultry waste, which is 1.2 kg (Novak *et al.*, 2016). The two treatments were homogeneously mixed together to form an evenly mixed blended biochar.

The total weight of the blended biochar (biochar + Poultry waste) used for this study was 2.4 kg, which was sprinkled with water and later left covered with nylon for two days for the treatment to react biologically.Soil for the experiments was taken from the nutrients depleted it was air-dried for two weeks and later sieved using 0.5 mm gauge sieve to remove pebbles, sticks, and roots from the topsoil. Three kilogram of soil sample was weighed into each polythene pot of 10,400 cm^3 (20 cm x 26 cm x 20 cm). Sixty-five pots were used comprising 13 treatments and 5 replications. The mixture of the treatments with the topsoil sample was carried out according to Claudia Kammann*et al.*, (2016). The mixing ratio used were 10 g kg^{-1}, 30 gkg^{-1}, 50 gkg^{-1} and 70 g kg^{-1} of topsoil respectively. The mixture of the topsoil and treatments in the polythene pots were left for three days without planting but were watered every day for proper decomposition and for easy uptake of the nutrients by the plants.

Table 1: Treatments Used in the Experiment

Treatments	**Code**
30 g of poultry waste	T1
90 g of poultry waste	T2
150 g of poultry waste	T3
210 g of poultry waste	T4
30 g of biocahr	T5
90 g of biochar	T6
150 g of biochar	T7
210 g of biochar	T8
30 g of blended biochar (15 g of biochar + 15 g of poultry waste)	T9
90 g of blended biochar (45 g of biochar + 45g of poultry waste)	T10
150 g of blended biochar (75 g of biochar + 75 g of poultry waste)	T11
210 g of blended biochar (105 g of biochar + 105 g of poultry waste)	T12
Control (No Treatment)	T13

Each treatment has 3 kg of topsoil

The Okra seed used was the lady finger variety and was planted on the 6^{th} of August. The seeds were planted 2.54

cm (1 inch) into the soil, three seeds per pot were planted and then thinned to one plant per pot a week after germination. The plants were watered once every day with a watering-can except the days when there was rainfall.

III. DATA COLLECTION

Plant height, plant diameter, number of leaves, leaf area and yield parameters were taken. Plant height and leaf area were measured using a transparent plastic ruler. The plant height was taken from the soil surface to the apical tip of the plant while meter rule was later used when the plants have grown beyond the length of a ruler. The leaf length and breadth were also measured with plastic ruler to obtain the leaf area. The leaf area was estimated as its length (L) and maximum width (W) parameters measured were put into the equation, $0.34(LW)^{1.12}$ as suggested by Omolaiye*et al.*, (2015). Plant diameter was measured using electronic digital vernier caliper and the number of leaves was also recorded after being counted. Data were collected every five days after planting.

The experiment was laid out in Completely Randomized Design (CRD). There were thirteen treatments including control which was replicated 5 times to form the population of 65 seedlings. Therefore, ANOVA and Duncan Multiple Range Test were used for the analysis. The poultry waste, biochar and topsoil were subjected to laboratory analysis for physico-chemical properties so as to have the knowledge of the initial mineral constituent of the treatments.

IV. RESULTS AND DISCUSSIONS

The physico-chemical properties of the poultry waste, biochar and blended biochar are shown in table 2 below. This shows that the soil used for this experiment was nutrient depleted and was appropriate for the study so as to easily observe the effects of the treatments applied.

Table 2: Physico-chemical Properties of the Soil, Poultry Waste and Blended Biochar before Experimentation

PARAMETERS	SOIL	POULTRY WASTE	BIOCHAR
Ph	6.62	8.21	9.94
Organic C(%)	0.98	5.49	57.2
Organic Matter(%)	1.69	9.46	99.17
Total Nitrogen(%)	0.049	0.47	4.96
Potassium	0.003 cmol kg^{-1}	0.48 %	0.36 %
Sodium	0.67 cmol kg^{-1}	0.52 %	0.05 %
Calcium	0.99 cmol kg^{1}	9 %	0.91 %
Manganese	240 mg/kg	0.022 %	0.0015 %
Copper	9.25 mg/kg	0.003 %	0.0005 %
Zinc	8.75 mg/kg	0.035 %	0.0086 %
Iron	275 mg/kg	0.53 %	0.16 %
Phosphorus	11.9 mg/kg	0.001 %	0.0007 %
Sand(%)	84.5	-	-
Clay(%)	13	-	-
Silt(%)	2.5	-	-
Ash Content(%)	-	-	36.2
Volatile Matter(%)	-	-	0.64
Moisture Content(%)	-	-	3.62

Variation in the Rate of Seed Germination and Growth Rate of Abelmuscusesculentus Plants (Okra)

To determine the rate of seed germination among the 13 treatments used, the samples were closely monitored. The plants started showing some variations from the 10^{th} day after planting. The variations observed were differences in the stem diameter and the dark brown coloration shown by the plants with high percentage of both biochar and blended biochar. Table 3 shows the rate at which the treatments affect the height of Okra.

Effects of Treatments on the Height of Okra

Table 3 shows comparative effects of poultry waste, biochar and blended biochar on the height development of Okra. At the 35^{th} day, it was observed that seedlings of Okra raised on soil treated with 90g of poultry waste (T2) performed best in height increase with an average of 32.58cm. Seedlings raised on soil treated with 150g of poultry waste (T3) performed second best with a mean of 26.26cm while the control (T13) performed least with a mean of 14.98cm. The results were significantly different ($P<0.05$) among the treatment. The poultry waste treatment resulted in higher plant height and this indicated the application of poultry waste as an excellent mean of soil amendment, providing both organic matter and nitrogen. According to Eneje and Uzoukwu, (2012), poultry waste improves the soil physical structures, initiating a good soil environment for plant growth.

Table 3: Effect of Poultry Waste, Biochar and Blended Biochar on Height Development of Okra Plant

Treatments	5th day	10th day	15th day	20th day	25th day	30th day	35th day
T1	2.78ab	7.12bcd	10.88bc	14.44de	16.14def	21.98def	26.40bcd
T2	3.28ab	7.42cd	11.90c	15.38e	18.80f	24.88f	32.58d
T3	2.26a	6.28abc	10.14bc	12.96bcde	15.72cdef	20.12cde	26.26cd
T4	2.18a	5.88ab	9.54bc	12.42bcde	15.12cde	19.74cde	25.84bcd
T5	3.20ab	6.42abc	8.94ab	10.42ab	12.30abc	15.42abc	20.40abc
T6	2.88ab	7.30bcd	9.42b	10.86ab	12.90abcd	15.88abc	18.96abc
T7	3.28ab	7.98d	9.60bc	11.46abcd	13.82bcde	16.14abc	19.16abc
T8	3.52b	7.18bcd	8.88ab	9.86ab	11.34ab	13.84ab	18.10ab
T9	2.84ab	6.88bcd	10.18bc	12.50abc	14.76bcde	18.74def	22.34abc
T10	3.48b	6.54abcd	9.66bc	11.18abc	14.00bcde	18.22cde	23.50bc
T11	3.30ab	7.28bcd	10.18bc	12.90bcde	14.26bcde	19.00cde	22.18abc
T12	3.84b	7.56cd	10.94bc	14.02cde	16.84ef	23.34df	23.00bc
T13	2.20a	5.32a	7.06a	9.28a	10.06a	12.72a	14.98a
LSD	1.01	1.27	2.01	2.68	3.26	4.29	6.85
% CV	26.4	14.6	16.5	17.4	17.9	18.3	23.9

Note: Means with the same letter are not significantly different from one another.

Least mean carries the first letter **'' a''**.

Effects of Treatments on the Stem Diameter of Okra

Table 4 shows that seedlings of Okra increase in stem diameter from the 5th day of assessment to the 35th day. At the 35th day, Okra raised on soil treated with 90g of poultry waste (T2) performed best in diameter increase with an average of 51.20mm ($P<0.05$) with high significant difference, closely followed by seedlings raised on soil treated with 210g of poultry waste (T4) with a mean of 50.20mm. The Okra plants raised on soil treated with 210g of biochar (T8) performed least in stem diameter increase with an average of 29.4mm. The result is consistent with the findings of Hardy and Bruno (2012) that biochar addition to soil can be a potential strategy for long-term carbon sequestration while improving ecosystem services.

Table 4: Effect of Poultry Waste, Biochar and Blended Biochar on Stem Diameter of Okra Plant

Treatments	5th day	10th day	15th day	20th day	25th day	30th day	35th day
T1	20.00b	23.20ab	27.40bcde	30.20bcd	34.80cd	39.40bcd	46.80cd
T2	18.60b	23.20ab	28.20cde	32.60cd	37.00cd	43.60d	51.20d
T3	16.00ab	23.60b	30.00de	32.60cd	37.00cd	41.00cd	49.00d
T4	14.00a	21.20ab	30.40e	34.60d	38.40d	43.00cd	50.20d
T5	16.60ab	19.60ab	22.20ab	23.40a	27.20a	29.80a	35.20ab
T6	19.00b	21.40ab	24.60abcd	28.00abc	31.20abc	36.00abcd	39.20bc
T7	16.80ab	18.80a	21.20a	24.40ab	26.60a	27.70a	32.00ab
T8	19.00b	20.20ab	21.80ab	25.40ab	27.20a	29.80a	29.40a
T9	16.80ab	19.60ab	23.00abc	25.80ab	29.40ab	31.30ab	37.40ab
T10	17.60ab	19.80ab	23.00abc	27.40abc	30.80abc	31.80b	37.20ab
T11	20.20b	21.00ab	22.60abc	25.20ab	27.40a	29.80a	37.80ab
T12	18.20ab	21.60ab	26.00abcde	28.60abc	30.00abc	34.40abc	37.60ab
T13	18.00ab	19.40ab	20.60a	23.00a	26.40a	28.40abc	32.00ab
LSD	3.64	3.72	4.90	5.26	6.31	7.85	7.88
%CV	16.1	14.0	15.6	14.9	16.0	18.0	15.7

Note: Means with the same letter are not significantly different from one another.

Least mean carries the first letter **'' a''**.

Effects of Treatments on the Leaf Production of Okra

Table 5 shows that the seedlings of okra raised on soil treated with 90g of blended biochar waste (T10) performed best in leaf production with an average of 7 leaves closely followed by seedlings raised on soil treated with 210g of blended biochar (T12) with an average of 6.8 leaves while seedlings raised on soil treated with 150g of biochar (T7) performed least in leaf production with an average of 4.4 leaves. Burrell et al. (2016) and Ouyang et al. (2013) have indicated that blended biochar can increase wet aggregate stability more in sandy than in silty clay or clayey soils. The organic particles of biochar may improve the particle bonding of large particles and promote soil aggregation in coarsetextured rather than in fine-textured soils. It is generally considered that biochar could have greater positive effects on carbon-depleted soils than on soils with a high organic carbon concentration. This is established in Table 1, where the experimental soil has 0.98 % of organic C and 84.5 % sandy, this explains the high production of leaf number by T10.

Table 5: Effect of Poultry Waste, Biochar and Blended Biochar on Leaf Production of Okra Plant

Treatments	5th day	10th day	15th day	20th day	25th day	30th day	35th day
T1	1.80	3.00	4.00abc	4.80cd	4.60de	4.00abc	5.60abcde
T2	2.00	2.80	4.20bc	5.00d	4.80e	6.0abc	5.80abcde
T3	1.80	2.80	3.80abc	4.40bcd	3.80cde	4.60bc	6.00bcde
T4	2.00	3.00	4.40c	4.40bcd	3.20abc	3.60abc	5.80abcde
T5	2.00	3.00	3.80abc	4.00ab	2.60ab	3.20abc	4.60ab
T6	1.80	2.80	4.00abc	4.00ab	2.60ab	3.00ab	5.00abc
T7	2.00	2.80	3.40a	3.60a	2.40a	2.80a	4.40a
T8	1.80	3.00	3.60ab	3.80ab	2.20a	3.20abc	5.20abc
T9	2.00	3.00	3.80abc	4.00ab	4.00cde	4.80c	5.40abc
T10	2.00	3.00	3.80abc	4.20abc	4.00cde	4.80c	7.00e
T11	1.80	2.80	3.80abc	4.20abc	3.20abc	4.20abc	6.40cde
T12	1.80	3.00	4.00abc	4.00ab	3.20abc	4.20abc	6.80de
T13	2.00	2.80	3.40a	4.00ab	3.60bcd	3.00ab	6.00bcde
LSD	0.39	0.39	0.65	0.63	1.02	1.44	1.35
% CV	15.9	10.4	13.3	11.9	24.1	30.2	18.7

Note: Means with the same letter are not significantly different from one another.

Least mean carries the first letter ‘’ **a**’’.

Effects of Treatments on the Leaf Area of Okra

The leaf area development of okra seedlings from the 5th day of assessment to the 35th day is presented in Table 6. At the 35th day, it was observed that the okra raised on soil treated with 90g of poultry waste (T2) performed best in leaf area with a mean of 47.5 cm^2. Seedlings raised on soil treated with 30g of poultry waste (T1) performed second best with a mean of 43.8 cm^2 while seedlings raised on soil without application of organic waste (T10) performed least in leaf area increase with a mean of 10.0 cm^2. This may be due to the delay in the release of blended biochar’ nutrients. This agrees with Lehmann,*et al.* (2015) observation that as pyrolysis temperatures increase (>400 °C), the remaining biochar material is predominately a C-enriched material that contains organic structures that resist oxidation and hence can have long residence times in soil. Amending soils with stable forms of biochar increases the size of C pools and long-term C sequestration Lehmann,*et al.* (2009).

Table 6: Effect of Poultry Waste, Biochar and Blended Biochar on Leaf Area of Okra plant

Treatments	5th day	10th day	15th day	20th day	25th day	30th day	35th day
T1	2.07abc	7.62cd	17.81cd	22.55c	31.5de	37.0cd	43.8d
T2	2.72cd	8.42c	24.83d	32.09d	38.3e	38.8d	47.5d
T3	2.46bcd	7.27bcd	16.35bc	19.09bc	23.8bcd	32.6bcd	37.5cd
T4	1.64a	6.37abcd	16.01bc	18.35bc	25.8cd	29.9bcd	37.0cd
T5	2.23abcd	4.53abc	6.40a	8.22ab	8.7a	12.4a	16.7ab
T6	2.31bcd	6.26abcd	8.43ab	9.78ab	9.2a	13.3a	20.0abc
T7	2.23abcd	6.83bcd	7.80a	8.50ab	10.0a	12.7a	16.9ab
T8	2.61bcd	4.28ab	5.74a	6.43a	7.8a	9.3a	12.1ab
T9	2.42bcd	6.83bcd	10.34a	12.71abc	15.4abc	20.9ab	27.9abcd
T10	2.70cd	6.31abcd	7.69abc	8.78ab	13.0ab	18.1ab	31.7bcd
T11	2.37bcd	7.36bcd	11.05a	13.05abc	15.3abc	21.2ab	28.4abcd
T12	2.86d	6.76bcd	11.96abc	12.55abc	16.8abc	23.1abc	42.6d
T13	1.96ab	3.44a	4.97a	6.06a	7.1a	8.4a	10.0a
LSD	0.59	2.67	7.20	9.35	11.02	13.93	17.27
%CV	19.7	33.3	49.4	53.7	50.7	51.4	47.5

Note: Means with the same letter are not significantly different from one another.

Effects of Treatments on the Yield of Okra

Table 7 shows the effects of poultry waste, biochar and blended biochar on the okra plants observed between45thto 55thday of assessment. The results indicated that seedlings of okra raised on soil treated with 150g of blended biochar waste (T11)performed best in yield production with an average of 3.20kg, closely followed by 90 g of blended biochar (T10) with an average of 2.20 kg. The least performance was observed on the control (T13) with an average of 0.94 kg. This results proposed to explain the synergism between biochars and poultry waste based on the improvement of soil structure and water availability (Novak et al., 2012), the promotion of beneficial microbes (Warnock et al., 2007), and the enhanced plant-available nutrients (Liu et al., 2012). A recent study (Kammann et al., 2015) showed that blended biochars became highly enriched with nutrients (i.e., nitrate, ammonium, and phosphate) and dissolved organic carbon that is slowly released in soil. In addition to nutrients, low- and high-molecular weight organic C compounds can accumulate on biochar surfaces and in pores, having the potential to affect plant yield.

Table 7: Effects of Poultry Waste, Biochar and Blended Biochar on the Yield of Okra

Treatment	45th day (Kg)	50th day (Kg)	55th day (Kg)
T1	0.84b	1.16ab	1.30bc
T2	0.61c	0.94b	1.12bc
T3	0.94b	1.04ab	1.22bc
T4	1.02ab	1.23ab	1.90b
T5	0.96b	1.25ab	2.03ab
T6	0.73bc	0.98b	1.86b
T7	0.58c	0.94b	1.03bc
T8	0.97b	1.09ab	1.18bc
T9	0.99b	1.21ab	1.93b
T10	1.31ab	2.06a	2.20ab
T11	1.87a	2.98a	3.20a
T12	0.62c	0.85b	1.06bc
T13	0.86b	0.91b	0.94c
LSD	0.75	0.74	0.55
% CV	11.4	13.5	12.8

Note: Means with the same letter are not significantly different from one another

V. CONCLUSION

The study has shown that addition of 50g kg^{-1}(T11)comprising 25g of biochar + 25g of poultry waste will improve the yield of Okra in the soil with the samephysico-chemical properties and the amount of poultry waste used for soil amendment reduced in quantity with the use of blended biochar. Therefore, poultry waste can be diverted for other uses. Going by the fruit yield performance of okra, the overall assessment shows that50g kg^{-1} (T11) gave the best result, followedby 30g kg^{-1} of the blended biochar (T10). They are therefore recommended in choosing the level of blended biochar to topsoil for Okra production.

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