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Morpho- Physio logical studies of soybean under the spraying of plant growth regulator [*Glycine max* (L.) Merill]

VW Bramhankar, VD Shende, RV Chahande and HS Deshmukh

Abstract
A soybean variety Phule Agrani was evaluated for foliar sprays of Etheral @ 150ppm (T1), Etheral @ 200ppm (T2), SNP @ 150µM (T3), SNP @ 200µM (T4), CCC @ 500ppm (T5), CCC @ 1000 ppm (T6), $FeSO_4$ @ 0.5% (T7), $FeSO_4$ @ 0.10% (T8), Water Spray (T9) and Absolute Control (T10) in randomized block design with three replication at MPKV, Rahuri during *Kharif*, 2015. The foliar sprays of CCC @ 500 ppm and @ 1000 ppm delayed the flowering period, arrested plant height, profuse branching, and maximum leaf area and leaf area index (LAI). Consistently, theses treatments maintained higher dry matter production and it's distribution in component parts of plant, LAD, LAR, SLW, AGR and CGR. In addition to this, SNP @ 200 µM and $FeSO_4$ @ 0.5% were also promising for maintaining dry matter production and growth parameters. According, the foliar sprays of CCC at lower followed by higher concentration @ 500 ppm and @ 1000 ppm and SNP @ 200 µM and $FeSO_4$ @ 0.5% were found better for recording higher yield and yield components. Therefore, the foliar sprays of CCC @ 500 ppm and @ 1000 ppm might be considered as better plant growth regulator for maintaining growth and yield improvement in soybean.

Keywords: Plant growth regulator, retardant, crop phenology, vegetative growth, growth function and yield components

Introduction
Soybean (*Glycine max* L.) is often designated as "Golden bean" and has become miracle crop of 20th century. It is a triple beneficial crop, which contains about 20% oil, 38 to 42% protein except methionine and cysteine. It also contains 26% carbohydrates, 4% minerals and 2% phospholipids. It is a rich source of vitamin A, B and D. The biological value of the soybean protein is as good as meat and fish protein. During 2015-16, the area under in India was 116.28 lakh/ha with production 73.797 lakh millions tones. Though it is grown in many states in India, Madhya Pradesh alone is producing 80 per cent of total production, Productivity of soybean in India is very low as compared to Brazil (2032 kg/ha) and U.S.A. (2441 kg/ha). Low yield of soybean under Indian conditions is attributed to many factors i.e. lack of location specific and disease and pest resistant varieties, lack of long shell life of soybean and production and sufficient quantity and quality oil seeds of high yielding varieties. Plant growth regulators and micronutrients are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development and ultimately enhance productivity of the crops. Plant Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance the effective partitioning of accumulates from source and sinks in the field crops. The use of plant growth regulators either as foliar spray or as seed treatment has brought spectacular results in both yield and quality of many vegetable crops. There is possibility that if plant growth regulators are used, the plant maturity may be hastened considerably. Some plant growth regulators like sodium nitroprusside (SNP) promote the cell elongation and hence hasten the maturity of plant. One of the most important roles of micronutrients is keeping balanced crop physiology. Zinc and iron take over different roles in crop, such as formation, partitioning and utilization of photosynthetic assimilates. Therefore, the present investigation was undertaken to study the effect of plant growth regulator and micronutrient on morpho-physiological and growth and yield variation in soybean.

Material and Methods
A soybean variety Phule Agrani was evaluated for foliar sprays of Etheral @ 150ppm (T1), Etheral @ 200ppm (T2), SNP @ 150µM (T3), SNP @ 200µM (T4), CCC @ 500ppm (T5), CCC @ 1000 ppm (T6), $FeSO_4$ @ 0.5% (T7), $FeSO_4$ @ 0.10% (T8), Water Spray (T9) and

Absolute Control (T10) in randomized block design with three replication at PG Farm, Department of Botany, MPKV, Rahuri during *Kharif*, 2015. The gross and net plot sizes were 5 x 2.70 m^2 and 4.80 x 1.80 m^2, respectively by adopting 45 x 10 cm spacing. Two spraying were given at the time of Initiation of flowering (38-40 Days) and at pod formation (58-60 Days) stage of the crop. The observations were recorded on crop phenology and vegetative growth, dry matter production and its distribution in component parts of plant, growth parameters and yield components. Five plants were randomly selected and uprooted for recording the observations on dry matter studies and growth parameters. Another five plants were tagged for recording the observations on leaf area, vegetative growth characters and yield component traits. Data were analyzed as per the method suggested by Panse and Sukhatme (1985) [13].

Results and Discussion

The vegetative phase governs the overall phenotypic expression of the plant and prepares the plant for next important reproductive phase. The root, stem, branches and leaves, all these parts constitute vegetative phase and perform specific functions. The treatment differences were statistically significant for days to 50% flowering, whereas, it was non-significant for days to initiation of flowering and physiological maturity (Table 1). The narrow range of variation was observed for days to initiation of flowering which is ranged between 38.20 (SNP @ 150 µM and 200 µM) and 39.10 days (Absolute Control). The foliar sprays of water (45.20 days) and absolute control (45.40 days) had required minimum number of days, whereas, foliar sprays of CCC @ 1000 ppm (49.77 days) and @ 500 ppm (49.10 days) required significantly higher number of days to 50% flowering. The days to physiological maturity exhibited narrow range variation which is ranged between 92.07 (Etheral @ 150 ppm) and 93.97 days (CCC @ 500 ppm). It indicated that, the foliar sprays of CCC delay the crop phenology. Similar results were reported by Akao *et al.* (1982) in soybean.

In the present investigation, the foliar sprays of CCC @ 500 ppm (66.17 cm) and @1000 ppm (66.53 cm) recorded significantly arrested plant height as compared to rest of the treatments. The foliar of sprays PGR's and micronutrients except CCC maintained significantly higher plant height over absolute control (70.30 cm) and water sprays (70.55 cm). It indicated that, CCC acts as a growth retardant, whereas, other PGR's and micronutrient $FeSO_4$ acts as growth promoters (Umezaki *et al.*, 1992). The foliar sprays of growth retardants CCC @ 500 ppm (6.57) and micronutrient $FeSO_4$ @ 0.10% (6.07) and @0.05% (6.00) maintained profuse branching. Jagmeet kaur *et al.*, (2015) reported the more number of branches plant^{-1} by application of CCC 500 mg l^{-1}. The foliar sprays of CCC @ 500 ppm 3.89 dm^2), Etheral @ 200 ppm (3.83 dm^2) and SNP @ 150 µM (3.83 dm^2) recorded the highest leaf area plant^{-1} as against Absolute Control (2.70 dm^2) and water spray (2.91 dm^2). The plant derives food and energy for its metabolic activities from a source. The primary function of leaves is carbon assimilation. Thus, leaf is the photosynthetic apparatus of the plant. On the basis of above results, It revealed that, the foliar sprays of CCC @ 500 ppm was found better for maintaining arrested plant height with profuse branching, higher leaf area and prolonged reproductive growth. The foliar sprays of PGR's and micronutrients exhibited statistically significant result for leaf area index at 60 DAS, 90 DAS and at harvest, however it was non-significant at 30 DAS (Table 1). The foliar sprays of CCC @ 1000 (5.01) and @ 500 ppm (4.83) at 60 DAS, CCC @ 500 ppm (3.61 & 0.864) and @1000 ppm (3.34 & 0.844) at 90 DAS and at harvest maintained higher leaf area index plant^{-1}.

Table 1: Crop phenology and vegetative growth of soybean influenced by various treatments of plant growth regulator and micronutrients

Treatments	Days to initiation of first flower	Days to 50% Flow-ering	Day to Physiol-ogical maturity	Plant height (cm)	Number of branches plant^{-1}	leaf area plant^{-1} (dm^2)	Leaf area index plant^{-1} (LAI)			
							30 DAS	60 DAS	90 DAS	Harv-est
Etheral 150 ppm	38.47	47.07	92.07	74.54	5.23	3.20	1.39	2.62	2.41	0.711
Etheral 200 ppm	38.23	46.80	93.67	76.95	5.93	3.83	1.45	2.86	2.49	0.852
SNP 150 µM	38.20	47.27	93.73	77.50	5.73	3.83	1.49	3.29	2.70	0.852
SNP 200 µM	38.20	47.17	93.67	79.40	5.93	3.80	1.56	3.92	2.93	0.844
CCC 500 ppm	38.13	49.10	93.97	66.17	6.57	3.89	1.47	4.83	3.61	0.864
CCC 1000 ppm	38.90	49.77	93.70	65.53	5.67	3.70	1.49	5.01	3.34	0.822
$FeSO_4$ 0.5%	38.90	45.83	93.29	73.30	6.00	3.08	1.53	2.95	2.45	0.685
$FeSO_4$ 0.10%	38.23	45.57	93.80	74.43	6.07	3.04	1.63	3.19	2.56	0.675
Water Spray	38.87	45.20	92.88	70.55	4.60	2.91	1.48	2.42	2.29	0.646
Absolute Control	39.10	45.40	92.65	70.30	4.50	2.70	1.59	2.34	2.13	0.600
GM	38.52	46.92	93.34	72.88	5.62	3.40	1.51	3.34	2.69	0.760
SE (M) $\pm$	0.341	0.345	0.46	0.26	0.220	0.067	0.067	0.143	0.089	0.015
CD at 5%	NS	1.024	NS	0.76	0.654	0.199	NS	0.425	0.264	0.046

The pattern of dry matter production and its distribution in plant parts has been of phenomenal interest to the research workers engaged in yield analysis. This method has been accepted as one of the standard methods of yield analysis. The data collected on dry matter at different time intervals would give the picture in quantitative terms as regards to accumulation and partitioning of the total dry matter among the plant parts thought the growth periods of the crop. In view of this, it was envisaged to know the pattern of dry matter accumulation and its distribution in component parts of plant. The overall functioning of the plant ultimately leads to formation and progressive accumulation of dry matter. All the physiological processes results into a net balance and accumulation of dry matter and hence, the biological productivity of plant is judged from their actual ability to produce and accumulate dry matter.

In the present investigation, the treatment differences were statistically significant for dry matter production and it's distribution in component parts of plant at 60 DAS, 90 DAS and at harvest (Table 2). The foliar sprays of CCC @ 500 ppm maintained higher dry matter production in leaves at 60 DAS (13.53 g plant^{-1}), 90 DAS (8.73 g plant^{-1}) and at harvest

(2.60 g plant^{-1}) followed by CCC @ 1000 ppm at 60 DAS (12.77 g plant^{-1}), 90 DAS (7.82 g plant^{-1}) and at harvest (2.10 g plant^{-1}). Consequently, these treatments also recorded higher dry matter in stems at 60 DAS (13.14 and 12.01 g plant^{-1}), 90 DAS (16.84 and 15.88 g plant^{-1}) and at harvest (12.75 and 11.23 g plant^{-1}), respectively. The dry matter accumulation in pods was also significantly higher in the treatment of foliar sprays of CCC @ 500 ppm (29.10 g plant-^{1}) and @ 1000 ppm (27.60 g plant-^{1}). On the basis of dry matter distribution in component parts of plant, the foliar sprays of CCC @ 500 ppm and @ 1000 ppm maintained higher dry matter production plant^{-1} at 60 DAS (28.57 and 27.53 g plant-^{1}), 90 DAS (38.10 and 35.50 g plant-^{1}) and at harvest (44.43 and 40.97 g plant-^{1}), respectively. Mishrinky *et al.* (1990) [10] reported that CCC and GA_3 increased dry mater per plant in the peas. Ravinchandran and Ramaswami (1991) reported the application of mepiquat chloride, cycocel and TIBA significantly increase the amount of dry matter production in soybean.

Table 2: Dry matter production and it's distribution in component parts of plant (g/ plant) influenced by various treatments of plant growth regulator and micronutrients in soybean

Treatments	30 DAS	60 DAS	90 DAS	Harv-est	30 DAS	60 DAS	90 DAS	Harv-est	Harv-est	30 DAS	60 DAS	90 DAS	Harv-est
	Leaves				Stem				Pods	Total			
Etheral 150 ppm	2.81	11.78	8.01	1.93	4.29	11.07	14.53	11.78	18.40	7.09	21.43	28.17	32.10
Etheral 200 ppm	2.97	12.16	8.48	2.43	4.71	11.75	14.97	12.08	19.90	7.68	22.80	30.07	34.40
SNP 150 µM	2.72	12.35	8.19	2.43	5.19	11.70	14.88	11.51	21.40	7.91	23.77	31.00	35.29
SNP 200 µM	2.79	12.81	8.67	2.60	5.07	12.04	15.30	12.15	24.30	7.85	25.97	33.97	39.07
CCC 500 ppm	2.69	13.53	8.73	2.60	5.01	13.14	16.84	12.75	29.10	7.69	28.57	38.10	44.43
CCC 1000 ppm	2.77	12.77	7.82	2.10	4.38	12.01	15.88	11.23	27.60	7.15	27.83	35.50	40.97
$FeSO_4$ 0.5%	2.64	11.78	7.85	1.90	5.13	12.42	15.59	11.25	21.70	7.77	23.17	30.73	34.83
$FeSO_4$ 0.10%	2.97	11.77	7.81	1.77	4.82	11.84	15.48	11.03	21.10	7.79	22.50	29.70	33.94
Water Spray	2.83	10.62	7.65	1.60	4.93	10.62	13.66	10.87	16.20	7.77	19.53	25.37	28.63
Absolute Control	2.94	9.78	6.70	1.57	5.19	9.96	13.55	10.45	16.40	7.99	19.57	25.33	28.37
GM	2.81	11.94	7.99	2.09	4.87	11.59	15.07	11.51	21.60	7.67	23.51	30.79	35.20
SE (M) ±	0.098	0.302	0.313	0.077	0.276	0.310	0.333	0.344	0.450	0.274	0.207	0.150	0.215
CD at 5%	NS	0.897	0.929	0.228	NS	0.922	0.988	1.021	1.360	NS	0.615	0.444	0.638

The knowledge of crop physiology through growth analysis technique, which involves tracing the history of growth and identifying the growth and yield factors contributing for yield variation, is a vital tool in understanding the crop behavior. This would be vital to the breeder as well as agronomist in tailoring suitable genotype or management technology for boosting up the growth and yield factors of the crop. Therefore, for a complete analysis of biological yield, it is necessary to investigate crop growth through computation of growth indices.

Watson (1956) concluded that, yield was dependent on size, efficiency and duration of photosynthetic system and hence, leaf area and leaf area duration contributed more to biological yield. The treatment differences were statistically significant for growth parameters at various stages of growth except for LAR and NAR between 90 DAS to harvest (Table 3). The foliar sprays of CCC @ 500 ppm and @ 1000 ppm recorded higher LAD at 30-60 DAS (94.53 and 97.60 days), 60-90 DAS (126.70 and 125.31 days) and at 90 DAS- harvest (26.96 and 24.44 days), respectively. Consistently, these treatments maintained higher LAR at 30-60 DAS (0.8194 and 0.7741 dm^2g^{-1}), 60-90 DAS (0.6077 and 0.5652 dm^2g^{-1}) and at 90 DAS- harvest (0.2433 and 0.2392 dm^2g^{-1}), respectively. Similarly, the foliar sprays of CCC @ 1000 ppm and @ 500 ppm recorded higher specific leaf area at 30-60 DAS (1.88 and 1.75 dm^2g^{-1}), 60-90 DAS (1.83 and 1.71 dm^2g^{-1}) and at 90 DAS- harvest (1.03 and 1.05 dm^2g^{-1}), respectively.

Table 3: Growth parameters influenced by various treatments of plant growth regulator and micronutrients in soybean

Treatments	30 - 60 DAS	60 - 90 DAS	90 DAS - Harvest	30 - 60 DAS	60 - 90 DAS	90 DAS - Harvest	30 - 60 DAS	60 - 90 DAS	90 DAS - Harvest
	Leaf area duration (Days)			Leaf area ratio (dm^2/g)			Specific leaf area (dm^2/g)		
Etheral 150 ppm	60.02	75.39	18.73	0.6121	0.4615	0.2377	1.24	1.15	0.93
Etheral 200 ppm	63.99	79.61	20.16	0.6149	0.4584	0.2391	1.27	1.16	0.93
SNP 150 µM	71.64	89.74	21.28	0.6806	0.4916	0.2408	1.43	1.31	0.98
SNP 200 µM	82.26	102.81	22.81	0.7278	0.5138	0.2340	1.58	1.44	1.03
CCC 500 ppm	94.53	126.70	26.96	0.7741	0.5652	0.2433	1.75	1.71	1.05
CCC 1000 ppm	97.60	125.31	24.44	0.8194	0.6077	0.2392	1.88	1.83	1.03
$FeSO_4$ 0.5%	67.22	81.02	18.81	0.6513	0.4498	0.2167	1.40	1.24	0.96
$FeSO_4$ 0.10%	72.40	86.25	19.39	0.7122	0.4958	0.2285	1.47	1.32	0.97
Water Spray	58.48	71.34	17.88	0.6416	0.4707	0.2492	1.30	1.17	0.92
Absolute Control	59.01	67.07	16.39	0.6514	0.4509	0.2345	1.39	1.22	0.91
GM	72.71	90.52	20.68	0.6885	0.4965	0.2363	1.47	1.35	0.97
SE (M) ±	2.46	2.86	0.56	0.0219	0.0146	0.0064	0.04	0.04	0.01
CD at 5%	7.30	8.49	1.65	0.0650	0.0434	NS	0.12	0.13	0.03
	Absolute growth rate (AGR, g day^{-1}/plant)			Net assimilation rate (NAR, g dm^{-2} day^{-1})			Crop growth rate (CGR, g m^{-2} day^{-1})		
Etheral 150 ppm	0.4509	0.2244	0.3278	0.0518	0.0182	0.0586	10.02	4.99	7.28
Etheral 200 ppm	0.4811	0.2422	0.3611	0.0520	0.0194	0.0553	10.69	5.38	8.02
SNP 150 µM	0.5316	0.2411	0.3578	0.0520	0.0180	0.0497	11.81	5.36	7.95
SNP 200 µM	0.6004	0.2667	0.4250	0.0523	0.0188	0.0557	13.34	5.93	9.44

CCC 500 ppm	0.6827	0.3178	0.5278	0.0541	0.0197	0.0454	15.17	7.06	11.73
CCC 1000 ppm	0.6644	0.2556	0.4556	0.0510	0.0188	0.0404	14.77	5.68	10.12
$FeSO_4$ 0.5%	0.5131	0.2522	0.3417	0.0527	0.0191	0.0549	11.40	5.60	7.59
$FeSO_4$ 0.10%	0.4842	0.2400	0.3531	0.0463	0.0191	0.0544	10.76	5.33	7.85
Water Spray	0.3911	0.1944	0.2722	0.0457	0.0172	0.0462	8.69	4.32	6.05
Absolute Control	0.3987	0.1922	0.2528	0.0456	0.0171	0.0512	8.86	4.27	5.62
GM	0.5198	0.2427	0.3675	0.0503	0.0185	0.0512	11.55	5.39	8.17
SE (M) ±	0.0077	0.0063	0.0222	0.0017	0.0004	0.0038	0.171	0.141	0.493
CD at 5%	0.0228	0.0188	0.0659	0.0051	0.0013	NS	0.507	0.418	1.464

Briggs *et al.* (1920) [3] defined absolute growth rate (AGR) as daily increment in dry matter over a given period. The AGR gives general idea regarding the pattern of growth at different growth stages. In the present investigation, the AGR was higher during 30-60 DAS and it was declined during 60-90 DAS and increased towards maturity. The foliar sprays of CCC @ 500 ppm and @ 1000 ppm recorded higher AGR during 30-60 DAS (0.6827 and 0.6644 g day^{-1} plant^{-1}), 60-90 DAS (0.3178 and 0.2556 g day^{-1} plant^{-1}) and 90 DAS- harvest (0.5278 and 0.4556 g day^{-1} plant^{-1}), respectively. Gregory (1926) had given the idea about net assimilation rate (NAR) as the rate of increase in dry weight per unit leaf area. In the present investigation, CCC @ 500 ppm and $FeSO_4$ @ 0.10% during 30-60 DAS (0.0526 and 0.0541 g dm^{-2} day^{-1}) and 60-90 DAS (0.0197 and 0.0191 g dm^{-2} day^{-1}) and SNP 200 @ µM and $FeSO_4$ @ 0.5% (0.0557 and 0.0549 g dm^{-2} day^{-1}) recorded higher NAR. Watson (1958) [18] and Nichiporovich (1964) [12] have reported the decline in NAR with increase in LAI. The crop growth rate (CGR) was higher during 30-60 DAS that declined rapidly during 60-90 DAS and increased steadily towards maturity. The foliar sprays of CCC @ 500 ppm and @ 1000 ppm maintained higher CGR during 30-60 DAS (15.17 and 14.77 g m^{-2} day^{-1}), 60-90 DAS (7.06 and 5.68 g m^{-2} day^{-1}) and 90 DAS- harvest (11.73 and 10.42 g m^{-2} day^{-1}), respectively. From the above results it evident that, the foliar sprays of CCC at lower concentration was better than higher concentration and other treatments for mai8ntaining the growth parameters of linseed crop.

Yield is compound character and is sum of the contributions made by a number of physiological characters. To the Plant Scientists, it is the net economic gains from the source and sinks capacity. Yield improvements have been achieved through directional selections for yield contributing traits (Akbar and Kamran, 2006) [2]. Pods, seed yield and 100 seed weight have been reported among the prominent grain yield determinants of cowpea (Brolmann and Stoffella, 1986; Siddique and Gupta, 1991) [8, 15]. They have been found to have reliable predictability on grain yields in grain legumes (Singh and Malhotra, 1970; Narsinghani *et al*., 1978; Dani, 1979) [5, 11, 16]. In the present investigation, the treatment differences were statistically significant for yield contributing characters as well as biochemical traits (Table 4).

Table 4: Yield components and chemical characters influenced by various treatments of plant growth regulator and micronutrients in soybean

Treatments	Pods plant^{-1}	Seeds pod^{-1}	100 seed weight (g)	Grain yield (kg ha^{-1})	Harvest index (%)
Etheral 150 ppm	48.4	2.73	11.0	2431	37.78
Etheral 200 ppm	50.1	2.93	11.5	2677	38.00
SNP 150 µM	50.9	2.87	13.5	2546	38.16
SNP 200 µM	57.5	2.87	13.6	2932	38.45
CCC 500 ppm	59.7	3.00	14.6	3144	41.08
CCC 1000 ppm	56.3	2.93	13.4	2566	39.31
$FeSO_4$ 0.5%	51.2	2.67	13.2	2527	38.12
$FeSO_4$ 0.10%	51.7	2.73	11.9	2512	38.32
Water Spray	40.7	2.13	10.5	1948	36.97
Absolute Control	39.5	1.93	9.7	1813	36.85
GM	50.6	2.68	12.3	2510	38.30
SE (M) ±	0.52	0.15	0.38	79.52	1.061
CD at 5%	1.57	0.46	1.14	236	3.152

The foliar sprays of CCC @ 500 ppm recorded higher number of pods plant^{-1} (59.7), seed pod^{-1} (3.00), 100 seed weight (14.6 g), grain yield (3144 kg ha^{-1}), harvest index (41.08%) and protein content (41.08%). The higher dose of CCC @ 1000 ppm was also found better for seed pod^{-1} (2.93), 100 seed weight (13.4 g), harvest index (39.31%). Devi *et al.* (2011) observed that ethrel @ 200 ppm gave highest number of pods plant^{-1}, 100 seed weight and seed yield ha^{-1}. Grewal *et al.*, (1993) [8] reported that cycocel improves the translocation of photosynthates and more protein content stored in the seeds might be due to improvement of translocation of photosynthates to the seeds.

It concluded that, the foliar sprays of CCC @ 500 ppm and @ 1000 ppm delayed the flowering period, arrested plant height, profuse branching, and maximum leaf area and leaf area index (LAI). Consistently, theses treatments maintained higher dry matter production and it's distribution in component parts of plant, LAD, LAR, SLW, AGR and CGR. In addition to this, SNP @ 200 µM and $FeSO_4$ @ 0.5% were also promising for maintaining dry matter production and growth parameters. According, the foliar sprays of CCC at lower followed by higher concentration @ 500 ppm and @ 1000 ppm and SNP @ 200 µM and $FeSO_4$ @ 0.5% were found better for recording higher yield and yield components, harvest index. Therefore, the foliar sprays of CCC @ 500 ppm and @ 1000 ppm might be considered as better growth regulator for yield improvement in soybean.

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