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Critical limits of phosphorus in relation to the growth and dry matter yield of green gram (*Vigna radiata* L.) in acid soils of Kakching District

Trishanku Kashyap, Herojit Singh Athokpam, N Surbala Devi, K Nandini Devi and N Gopimohan Singh

Abstract
In a pot culture experiment, the response of Green gram plants (*Vigna radiata* L.) cv. DGGS-4 to phosphorus was studied on twenty acidic soils of Kakching district, Manipur. The soils were found to be acidic with a mean pH of 4.98, organic carbon content 16.76 g kg^{-1}, EC 0.22 dSm^{-1}, CEC 14.01 cmol (p^+) kg^{-1}, and clay content ranged from 19.79 to 83.12 per cent. Dry matter yield in the plants increased significantly with the increase of phosphatic fertilizer application. The initial P concentration in plants as well the P uptake increased significantly with increase in phosphatic fertilizers. Bray 1 (r=0.774**) and Bray 2 (r=0.741**) extracted phosphorus was found significantly correlated with Bray's per cent yield. The critical limits of phosphorus in soils were found to be 20 kg P_2O_5 ha^{-1} for Bray 1 extracted soil phosphorus and 26 kg P_2O_5 ha^{-1} for Bray 2 extracted soil phosphorus. The critical limit of phosphorus in plant tissues were found to be 0.43 per cent.

Keywords: Pot-culture, acidic soil, dry matter, P-concentration, P-uptake, Critical-limit

1. Introduction
Phosphorus is one of the three primary nutrients and the second most important element after nitrogen for growth and development of every plants. Phosphorus is taken up from the soil solution by plant roots principally as primary orthophosphate ions ($H_2PO_4^-$, pH- 6.5) and to a lesser extent as secondary orthophosphate ions (HPO_4^{2-}, pH- 7.2).

The North-East Region of India has geographical area of 26.3 million hectares and almost 85% of the soils are moderate to strongly acidic. Phosphorus deficiency is the main limiting factor for crop production in acidic soils and therefore, requires the application of phosphatic fertilizers for optimum plant growth and production of food and fibre.

Green gram [*Vigna radiata* L.] is an important pulse crop having high nutritive value. It contains about 25 per cent protein along with amino acids such as arginine, histidine, lysine and tryptophan etc. It not only plays an important role in human diet but also in improving the soil fertility by fixing the atmospheric nitrogen. There is great variability in green gram varieties for yield performance during summer season. Phosphorus is an integral component of virtually all the biochemical compounds that make plant life possible. Its response is known in presently available green gram varieties. Nitrogen as well as phosphorus (Singh *et al.* 2008) is essential for normal growth and development of green gram. Phosphorus application to green gram increases plant growth, yield attributes and grain yield. Phosphorus promotes early root formation and the formation of lateral, fibrous and healthy roots which is very important for nodule formation and to fix atmospheric nitrogen. Correlation of nutrients content of plants in stages of their growth and their yield parameters is utmost for determining the critical nutrients for optimum growth. No such study for green gram plants in Kakching district soils has been conducted earlier and hence the present study has been undertaken.

2. Materials and Methods
Twenty soil samples (15 cm depth) were collected from rice fields of Kakching district, Manipur and the available phosphorus in kg P_2O_5 ha^{-1} was extracted using six major extractants *viz.*, Bray 1 and Bray 2 (Bray and Kurtz, 1945) [1], Mehlich 1(Mehlich, 1937) [7], Mehlich 3, Troug (Troug, 1930) [13] and Olsen (Olsen *et al.*, 1954) [8]. The samples were analyzed for pH (Jackson, 1973) [4], EC (Jackson, 1973) [4], Organic carbon (Walkley and Black, 1934) [14], CEC (Boarh *et al.*, 1987), available N (Subbiah and Asija, 1956) [11], available K (Jackson, 1973) [4] and available Ca and Mg (Chopra and Kanwar, 1976) [2].

A pot culture experiment was executed in the Dept. of SSAC, CAU with the objectives of studying the critical level of both plant as well as soil during February-March, 2021. Twenty locations from Kakching district, Manipur were collected and were air dried under shade and further ground with a mortar and pest-led and the processed samples (<2mm) were subjected to analysis for physic-chemical properties using the standard procedure. Poly pots of 4kg capacity each were filled with 3 kg of collected soils and arranged in completely randomized design (CRD) with the treatment of 30, 40 and 50 kg P_2O_5 ha^{-1}. Based on weight of pots, and fertilizer requirement, SSP was applied in each pot, separately for separate treatments. Nitrogen and Potassium were applied through Urea and Muriate of potash, respectively to each pot in constant dose. Four replications were carried out for each treatments. Ten seeds of green gram were sown in each pot, which were further thinned downed to 5 after germination. Generalized irrigation was followed. At 45 days after sowing, the plants were harvested and washed in running tap water to remov dirt followed by distilled water and were dried in an oven at 65 °C for 48 hours and the dry matter yield was recorded.

Bray's per cent yield of pea was calculated as

$$\text{Bray's percent yield} = \frac{\text{Yield in control pots x 100}}{\text{Maximum yield in fertilizer treated pots}}$$

The critical levels of both soil and plant were estimated by graphical procedure of Cate and Nelson (1965).

3. Results and discussion:

3.1 Soil physic-chemical properties

The soil pH values ranged from 4.58 to 5.67 with the mean value of 4.98, E.C. values ranged from 0.14 dSm^{-1} to 0.31 dSm^{-1} at 25°C with a mean value of 0.22 dSm^{-1}, organic carbon content in the soils ranged from 10.55 g kg^{-1} to 26.60 g kg^{-1}, available nitrogen ranged from 75.26 kg ha^{-1} to 305.50 kg ha^{-1} with a mean value of 212.66 kg ha^{-1}, available potassium present in these soils varied from 49.63 kg ha^{-1} to 160.50 kg ha^{-1}, exchangeable calcium ranged from 1.25 [cmol (p^+) kg^{-1}] to 4.40 [cmol (p^+) kg^{-1}], exchangeable magnesium from 0.15 [cmol (p^+) kg^{-1}] to 4.30 [cmol (p^+) kg^{-1}]. The cation exchange capacity of the soils was between 9.00 [cmol (p^+) kg^{-1}] and 19.00 [cmol (p^+) kg^{-1}] with a mean of 14.01 [cmol (p^+) kg^{-1}].

3.2 Dry matter yield

The results in Table 2., showed that the dry matter yield of Green gram, cv. DGGS-4 was influenced by phosphorus application inspite of the initial phosphorus status in the soils. As well as the different levels of phosphorus concentration. The dry matter yield in the control varied from 1.09 to 2.86 g/pot (mean 2.15 g) as compared with 1.65 to 2.90 g/pot (mean 2.42 g) in 30 kg P_2O_5 ha^{-1},1.76 to 3.58 in 40 kg P_2O_5 ha^{-1} and 2.47 to 4.57 g/pot (mean 2.63 g) in 50 kg P_2O_5 ha^{-1} (mean 3.03 g) respectively. Phosphorus application @ 50 kg P_2O_5 ha^{-1} was found significantly superior to other treatments. There was gradual increase in the dry matter yield of green gram crops accordingly with the increase in phosphorus application. Pangalthabi village showed the highest value whereas Sora village showed the lowest dry matter yield. It was recorded that dry matter yield was highest at 50 kg P_2O_5 ha^{-1}. Dry matter yield of green gram due to different treatments of phosphorus was found significant at 0.05 or 0.01 level of probability.

3.3 Phosphorus content

The results in Table 3, shows phosphorus concentration in the plants at control. Phosphorus concentration in the plants ranged from 0.25 to 0.57 per cent (mean 0.42 per cent) in comparison to 0.27 to 0.62 per cent (mean 0.44 per cent) in 30 kg P_2O_5 ha^{-1}, 0.29 to 0.69 per cent (mean 0.49 per cent) in 40 kg P_2O_5 ha^{-1} and 0.37 to 0.89 per cent (mean 0.58 per cent) in 50 kg P_2O_5 ha^{-1}. Phosphorus application was found to influence phosphorus content in the plants. At 50 kg P_2O_5 ha^{-1} the plants showed highest phosphorus content in comparison to other treatments (Table 2.). The phosphorus content in the plant due to phosphorus application was significantly different at 0.05 or 0.01 level of probability.

3.4 Phosphorus uptake

The results in Table 2. shows phosphorus concentration in the plants at control. Phosphorus concentration in the plants ranged from 3.39 to 16.10 mg/pot (mean 9.24 mg) in comparison 5.42 to 15.29 mg/pot (mean 10.67 mg) in 30 kg P_2O_5 ha^{-1}, 6.06 to 19.80 mg/pot (mean 12.90 mg) in 40 kg P_2O_5 ha^{-1} and 10.20 to 24.83 mg/pot (mean 17.50 mg) in 50 kg P_2O_5 ha^{-1}. Phosphorus application was found to influence phosphorus content in the plants. At 50 kg P_2O_5 ha^{-1} the plants showed highest phosphorus content in comparison to other treatments (Table 1.). The phosphorus content in the plant due to phosphorus application was significantly different at 0.05 or 0.01 level of probability.

3.5 Correlation

Out of the six extractants used, Bray 1 and Bray 2 showed positive and significant correlation with Bray's percent yield (Table.4) for green gram cv. DGGS-4. Bray 1 showed the highest degree of correlation with Bray's percent yield (r=0.774**) followed by Bray 2 (r=0.741**) and hence based on these results, Bray 1 is used as the phosphorus extractant for growing green gram plants in soils of Kakching district, Manipur.

3.6 Critical limit of P in soil and plant

The critical limits of available phosphorus extracted by Bray 1 and Bray 2 extractants were estimated according to the Cate and Nelson graphical procedure (1965). Critical limit for phosphorus in the soils of Kakching district, Manipur varied based on the two Extractants used. The critical limit of P in soil was 20 kg for Bray 1 (Fig. 1) Extractants and 26 kg for Bray 2 extractant (Fig. 2). Bray 1 extractant showed higher degree of correlation with other plant parameters. The critical limit of phosphorus in the green plants was found to be 0.43 per cent (Fig. 3) (Watham *et al.*, 2014) [15].

3.6 Tables

Table 1: Some physico-chemical properties of soil

Soil No.	pH	E.C. (dSm^{-1})	Organic C ($g\ kg^{-1}$)	Av. N ($kg\ ha^{-1}$)	Av. K ($kg\ ha^{-1}$)	Ca [cmol (p^+) kg^{-1}]	Mg [cmol (p^+) kg^{-1}]	CEC [cmol (p^+) kg^{-1}]	Sand (%)	Silt (%)	Clay (%)
1	4.70	0.20	11.30	112.90	88.39	2.90	2.90	11.20	17.80	20.70	61.50
2	5.60	0.21	22.00	275.97	108.10	2.70	3.20	12.56	11.20	25.00	63.80
3	4.80	0.18	14.46	188.16	103.56	3.90	2.60	14.60	6.20	17.50	76.30
4	4.70	0.23	10.85	125.45	98.23	2.65	3.45	17.60	50.92	29.29	19.79
5	5.02	0.23	13.50	75.26	49.63	2.50	2.30	18.20	15.90	27.80	56.30
6	4.84	0.26	20.08	276.16	136.50	2.60	1.90	14.40	9.60	15.00	75.40
7	5.30	0.24	15.00	213.25	107.68	2.60	1.40	9.00	8.70	8.18	83.12
8	5.20	0.29	12.50	150.80	106.08	3.20	0.80	19.00	11.20	40.00	48.80
9	5.02	0.22	17.10	290.96	152.58	1.25	1.15	12.00	12.10	35.00	52.90
10	4.80	0.20	18.80	287.50	130.34	2.75	0.15	9.20	7.10	35.00	57.90
11	4.60	0.24	26.60	301.05	152.86	3.10	2.50	18.20	14.60	10.00	75.40
12	4.77	0.18	25.83	305.50	160.50	4.40	3.40	11.60	29.60	32.50	37.90
13	4.69	0.15	11.40	146.35	95.89	2.50	0.70	15.60	19.60	25.00	55.40
14	4.89	0.18	15.30	203.23	100.36	2.20	4.30	11.40	17.10	34.93	47.97
15	5.67	0.17	11.70	142.73	101.52	3.50	0.60	15.00	8.70	30.00	61.30
16	4.58	0.22	21.93	263.60	124.30	2.75	0.35	14.40	22.10	10.60	67.30
17	5.58	0.31	20.96	249.30	136.50	2.20	1.30	13.50	7.10	42.50	50.40
18	4.90	0.17	10.55	130.59	78.80	2.70	0.70	18.60	35.30	25.90	38.80
19	4.75	0.30	13.70	215.89	116.80	3.00	1.60	14.00	6.99	19.21	73.80
20	5.25	0.14	21.60	298.59	146.45	2.85	1.81	10.20	41.96	23.21	34.83
Mean	4.98	0.22	16.76	212.66	114.75	2.81	1.86	14.01	17.69	25.37	56.95

Table 2: Effect of phosphorus application on dry matter yield, phosphorus concentration and its uptake by green gram

Soil No.	Bray 1	Dry matter yield (g/pot) P_2O_5 level ($kg\ ha^{-1}$)				Mean	Bray's % yield	P concentration of plants in control	P uptake by plants (mg/pot) P_2O_5 level ($kg\ ha^{-1}$)				Mean	Bray's % P uptake
		0	30	40	50				0	30	40	50		
1	18.50	2.56	2.62	2.66	2.91	2.69	87.97	0.35	8.89	13.65	17.40	20.60	15.14	43.11
2	21.36	1.32	1.89	2.08	2.61	1.98	50.57	0.40	5.32	7.80	10.30	13.10	9.13	40.74
3	9.84	2.34	2.53	2.65	2.60	2.53	88.30	0.50	11.72	11.98	13.70	14.30	12.93	82.04
4	10.26	2.61	2.62	2.64	2.86	2.68	91.26	0.52	13.50	13.84	14.10	20.20	15.41	66.73
5	20.53	1.31	2.42	2.81	2.85	2.35	45.96	0.42	5.56	9.50	12.80	17.20	11.27	32.29
6	20.75	1.64	1.70	1.76	2.49	1.90	65.46	0.41	6.76	7.39	7.76	11.81	8.43	57.07
7	21.60	2.86	2.90	2.93	2.99	2.92	95.65	0.47	13.60	15.29	18.60	19.43	16.73	70.15
8	12.82	2.62	2.71	2.79	3.88	3.00	67.53	0.39	10.40	11.50	13.10	24.83	14.96	41.85
9	18.60	2.58	2.62	2.70	4.39	3.07	58.77	0.47	12.50	12.08	11.90	20.12	14.15	60.79
10	21.25	2.75	2.87	2.99	2.97	2.90	91.67	0.36	9.98	15.25	19.80	19.70	16.18	50.59
11	23.50	2.80	2.82	2.85	2.90	2.84	96.55	0.57	16.10	10.95	6.06	21.22	13.58	75.83
12	14.31	1.49	1.65	1.87	2.79	1.95	53.40	0.30	4.47	8.82	13.40	10.20	9.22	43.74
13	13.61	2.66	2.68	2.70	2.82	2.72	95.02	0.47	12.60	10.56	9.03	14.60	11.70	86.18
14	23.42	1.38	1.85	2.20	2.75	2.05	50.18	0.27	3.67	6.81	11.50	11.50	8.37	32.00
15	16.32	1.38	2.09	2.76	2.85	2.27	48.42	0.25	3.39	5.42	8.01	18.52	8.84	18.35
16	15.54	2.38	2.42	2.49	2.64	2.48	90.15	0.39	9.36	8.00	11.90	13.30	10.64	70.45
17	22.50	2.31	2.35	2.43	2.47	2.39	93.15	0.49	11.30	11.82	12.60	22.14	14.47	51.08
18	15.53	1.09	2.67	3.05	3.13	2.49	34.93	0.44	4.81	7.67	15.70	16.70	11.22	28.85
19	20.56	2.51	2.23	2.56	4.57	2.97	54.92	0.45	11.30	12.15	14.00	25.59	15.76	44.28
20	16.27	2.15	2.79	3.58	3.03	2.89	64.24	0.42	9.61	12.89	17.20	15.00	13.68	63.86
Mean	17.85	2.14	2.42	2.63	3.03	2.55	71.21	0.42	9.24	10.67	12.94	17.50	12.59	53.00
C.D. at 5% for Soil Mean= 0.29								C.D. at 5% for Soil Mean= 3.12						
C.D. at 5% for P level Mean= 0.13								C.D. at 5% for P level Mean= 1.22						
C.D. at 5% for PxSoil Mean= 0.58								C.D. at 5% for PxSoil Mean= 5.21						

Table 3: Effect of phosphorus application on phosphorus concentration in green gram plants

Soil No.	Bray 1	P concentration in plants (%) P2O5 Levels (kgha-1) 0	30	40	50	Mean
1	18.50	0.35	0.41	0.66	0.71	0.53
2	21.36	0.40	0.43	0.49	0.50	0.46
3	9.84	0.50	0.48	0.52	0.55	0.51
4	10.26	0.52	0.50	0.53	0.71	0.57
5	20.53	0.42	0.43	0.46	0.60	0.48
6	20.75	0.41	0.42	0.44	0.48	0.44
7	21.60	0.47	0.53	0.63	0.65	0.57
8	12.82	0.39	0.40	0.41	0.64	0.46
9	18.60	0.47	0.46	0.49	0.46	0.47
10	21.25	0.36	0.39	0.40	0.66	0.45
11	23.50	0.57	0.62	0.69	0.73	0.65
12	14.31	0.30	0.31	0.32	0.37	0.33
13	13.61	0.47	0.48	0.50	0.52	0.49
14	23.42	0.27	0.36	0.41	0.42	0.37
15	16.32	0.25	0.27	0.29	0.65	0.37
16	15.54	0.39	0.42	0.48	0.50	0.45
17	22.50	0.49	0.51	0.52	0.89	0.60
18	15.53	0.44	0.48	0.51	0.53	0.49
19	20.56	0.45	0.47	0.55	0.56	0.51
20	16.27	0.42	0.45	0.48	0.50	0.46
Mean	17.85	0.42	0.44	0.49	0.58	0.48

C.D. at 5% for Soil mean = 0.09
C.D. at 5% for P level mean = 0.02
C.D. at 5% for P x Soil mean= 0.14

Table 4: Simple correlation co-efficient between the different forms of phosphorus and yield parameters of green gram

Sl. No.	Extractants	Dry matter yield (control)	P content (control)	P uptake (control)	Bray's % yield	Bray's % uptake
1	Bray 1	0.669**	0.506*	0.694**	0.709**	0.774**
2	Bray 2	0.428	0.434	0.489*	0.615**	0.741**
3	Mehlich 1	0.078	0.332	0.188	0.201	0.129
4	Mehlich 3	0.438	0.537*	0.587**	0.254	0.451*
5	Troug	0.352	0.382	0.421	0.159	0.361
6	Olsen	0.066	-0.149	-0.015	0.015	-0.212
7	Saloid-P	0.199	0.159	0.208	0.142	-0.055
8	Iron-P	0.272	0.273	0.298	0.349	0.287
9	Aluminium -P	0.346	0.422	0.415	0.291	0.297
10	Reductant soluble-P	0.262	0.354	0.346	0.282	0.299
11	Occluded-P	-0.467*	-0.295	-0.474*	-0.281	-0.354
12	Calcium-P	0.163	0.125	0.154	0.172	0.011
13	Organic-P	-0.207	0.032	-0.138	-0.161	0.020
14	Total-P	-0.005	0.246	0.092	0.057	0.181

3.7 Graphs

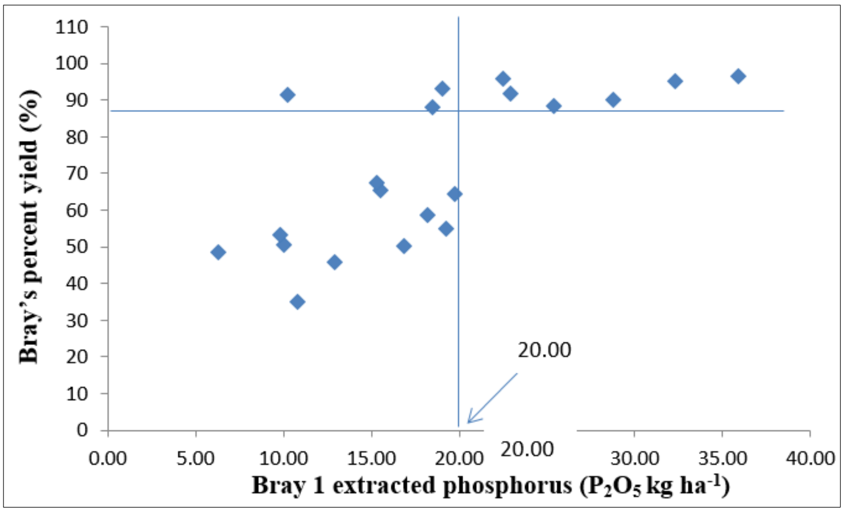

Fig 1: Relationship between Bray 1 extracted P_2O_5 (kg ha^{-1}) and Bray's percent yield

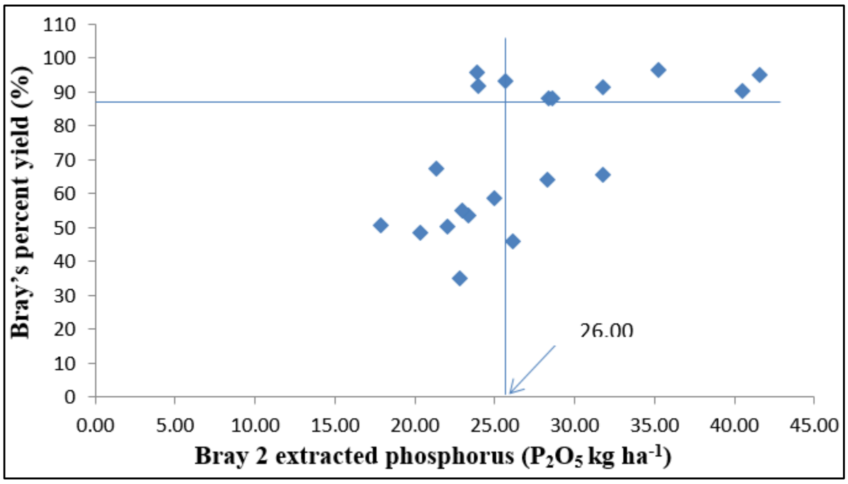

Fig 2: Relationship between Bray 2 extracted P_2O_5 (kg ha^{-1}) and Bray's percent yield

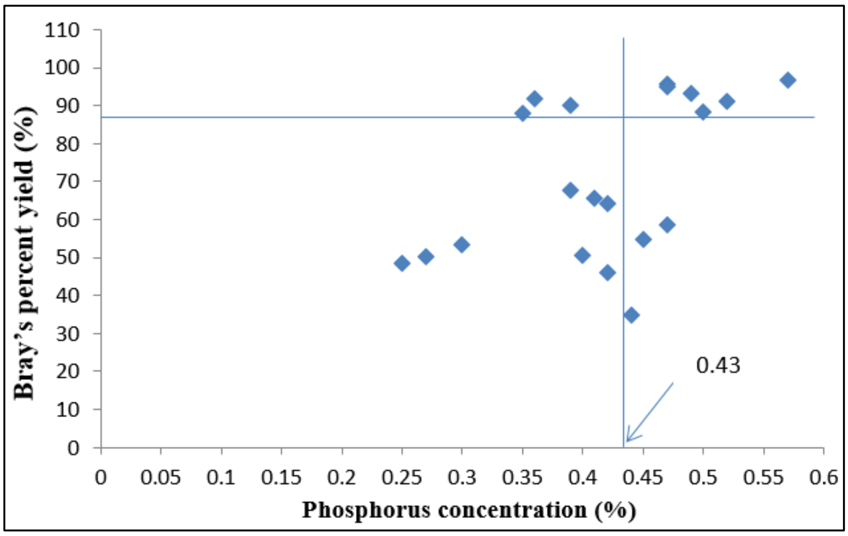

Fig 3: Relationship between Phosphorus concentration (%) and Bray's percent yield

5. Conclusion

By using the graphical method of critical limit determination by Cate and Nelson (1965), the critical limits of available phosphorus in the study was found to be 20 kg P2O5 ha-1 for Bray 1 extracted phosphorus (Fig. 1) and 26 kg P2O5 ha-1 (Fig. 2) for Bray 2 extracted phosphorus. Following the same procedure, critical limit of phosphorus in green gram plants (45 DAS) was found to be 0.43 per cent (Fig. 3). Plants with phosphorus concentration below this level will be considered P deficient at the critical stage and would require external application of P fertilizers.

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