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FERTILIZER PRESCRIPTION EQUATION FOR DESIRED YIELD TARGETS OF SOYBEAN-CHICKPEA CROPPING SYSTEM IN VERTISOLS UNDER INTEGRATED PLANT NUTRIENT SYSTEM

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ABSTRACT
A field experiment was conducted in Soybean-Chickpea cropping system with integrated use of FYM and fertilizer to estimate the fertilizer requirement for targeted yield of soybean and chickpea at the Instructional farm of Indira Gandhi Agricultural University, Raipur (C.G). Based on the experiment the nutrient requirement for producing one quintal of soybean grain was 0.35 kg S, 0.46 kg P and 2.25 kg K and 0.47 kg S, 0.46 kg P and 2.40 kg K were required for one quintal grain production of chickpea. The percent contribution from soil was 27.48 % S, 49.20% P and 8.09% K for soybean and that for chickpea were 21.53 % S, 30.03 % P and 5.40 % K respectively. The contribution of fertilizer towards crop response was 14.75, 15.79 and 56.05% for S, P and K, respectively for soybean and 12.06, 10.01 and 38.62 % for chickpea. The contribution of FYM was 2.93, 5.20 and 5.65 for soybean and 1.93, 4.42 and 7.19 percent S, P, K for chickpea crop. Based on these basic parameters, fertilizer adjustment equation for S, P and K were formulated for different yield targets of soybean and chickpea crop based on soil nutrients level using FYM as INM component.

INTRODUCTION

Soybean and chickpea crops are the most important pulse crop of the world that supplements the protein requirement of our population. In India, soybean is grown in an area of 10.63 million hectares with an annual production of about 12.36 million tones and productivity of 1163 kg/ha and chickpea is grown in an area of 8.98 million hectares with an annual production of about 8.57 million tones and productivity of 954 kg/ha. (Annon., 2015). The area and production of soybean in Chhattisgarh are 105.1 thousand hectare and 100.3 thousand tonnes respectively and chickpea are 259.2 thousand hectare and 245.1 thousand tonnes respectively. Soybean and chickpea productivity in Chhattisgarh is about 954 kg ha^{-1} and 946 kg ha^{-1} (Agriculture and Cooperation Report, Ministry of Agriculture, Government of India 2014-15).

Integrated nutrient management strategies that include site-specific knowledge of crop nutrient requirements, soil nutrient supply, and recovery efficiency of applied fertilizer, are required to sustain high yields and maintain or build up soil fertility at a level that ensures maximum efficiency from nutrient inputs (Singh *et al*., 2014 and Kumar *et al*., 2014). Several approaches have been used for fertilizer recommendation based on chemical soil test so as to attain maximum yield per unit of fertilizer use. Among the various approaches, the target yield approach (Ramamoorthy *et al*., 1967) has found popularity in India (Subba Rao and Srivastava, 2000).

This method not only estimates soil test based fertilizer dose but also the level of yield the farmer can achieve with that particular dose. The basic data required for formulating fertilizer recommendation using this approach are nutrient requirement for a unit grain yield, nutrient contribution from soil *i.e*., nutrient supplying capacity of soil and the nutrient contribution from fertilizer *i.e*., recovery efficiency of fertilizer nutrient. Quantitative fertilizer requirements based on this approach have been estimated for specific yield target of crops like rice and wheat (Ahmed *et al*., 2002 and Subba Rao and Srivastava, 2000). FYM is a better source of plant nutrients (Nayak *et al*., 2014). It has potential in modifying the soil physical properties and improving crop yields and has become an important part of integrated nutrient supply system in developing countries. Recommendations based on Soil Test Crop Response Correlation concept are more quantitative, precise and meaningful because combined use of soil and plant analysis is involved in it. It gives a real balance between applied nutrients and the available nutrients already present in the soil. Keeping these aspects in view and non availability of quantitative study of fertilizers requirements based on target yield for soybean and chickpea in chhattisgarh plains this study was conducted.

MATERIALS AND METHODS

A field experiment was conducted on soybean (JS-9752) and chickpea (JG-130) cropping system in *typical fine montmorillonitic, hyperthermic, udic chromustert*. at the Instructional farm of Indira Gandhi Krishi Vishwavidyalaya,

Raipur (Chhattisgarh) during the year 2013-14. The experimental site is located at eastern part of Raipur city and situated in mid-eastern part of Chhattisgarh state and lies at 21º 16" N latitude and 81º36" E longitudes with an attitude of 298.56 meter above the mean sea level. The region comes under sub-humid climatic condition. The average annual rainfall of the area is 1400-1600 mm. The soil was clayey in texture, dark brown in color, pH 8.03, Organic carbon 5.80 g kg^{-1}, EC 0.18 dSm^{-1} and CEC 36.32 C mol (p^+) kg^{-1}. The available S, N, P and K status of the representative sample were 25.85, 238, 19.3 and 486 kg ha^{-1}, respectively. The inductive-*cum* fertility gradient approach of Ramamurthy *et al*. (1967) was followed for conducting the experiment. Three fertility gradients were created by dividing the experimental field in to three equal strips and denoted as L_0, L_1 and L_2 which were fertilized with $N_0P_0K_0$, $N_1P_1K_1$ and $N_2P_2K_2$ levels. These fertility gradients were fertilized as L_0: 0:0:0 kg ha^{-1} N, P_2O_5 and K_2O, L_1: 100:75:50 kg ha^{-1} and L_2: 200:150:100 kg ha^{-1} N, P_2O_5 and K_2O, respectively. The sources of N, P and K were used as Urea, SSP, and MOP, since SSP contains sulphur (12%) along with phosphorus hence, variations with respect to soil sulphur in three fertility strips were estimated and soil N was not considered due to leguminous crop (soybean and chickpea) under study. After the harvest of exhaust crop, the main complex experiment with soybean was carried out in subsequent *kharif* season. Fodder maize crop was grown during summer season 2013 as an exhaust crop so that the fertilizer could undergo transformation in the soil with plant and microbial agencies and thus become a part of soil system. By growing the exhaust crop, the operational range of soil fertility was created in fertility strips which were evaluated in terms of variation in fodder yield, uptake and soil test values. After the harvest of the fodder crop, all strips were divided in to three equal sizes across the fertility gradient and FYM levels (0, 5 and 10 t ha^{-1}) were imposed in each fertility gradient that was treated as block. After the harvest of soybean crop, the experiment with chickpea was carried out in subsequent rabi season. Again after the harvest of the soybean crop, all strips were divided in to three equal sizes across the fertility gradient and FYM levels (0, 5 and 10 t ha^{-1}) were imposed in each fertility gradient that was treated as block. Twenty one selected fertilizer treatments ($S_{20}P_{90}K_{60}$, $S_{30}P_{60}K_{30}$, $S_{20}P_{60}K_{90}$, $S_{20}P_{90}K_{90}$, $S_{30}P_{30}K_{30}$, $S_{10}P_{60}K_{30}$, $S_{20}P_{60}K_{30}$, $S_{20}P_0K_{60}$, $S_{30}P_{90}$ K_{30}, $S_{30}P_{90}K_{90}$, $S_{20}P_{60}K_{60}$, $S_{20}P_{30}K_{60}$, $S_{20}P_{30}K_{30}$, $S_{10}P_{30}K_{30}$, $S_{30}P_{90}K_{60}$, $S_{30}P_{60}K_{90}$, $S_{20}P_{60}K_0$, S_{30} $P_{60}K_{60}$, $S_{10}P_{60}K_{30}$, $S_{10}P_{30}K_{60}$, $S_0P_{60}K_{60}$) comprising different combinations of S (0,10,20 and 30 kg ha^{-1}), P_2O_5 (0, 30, 60 and 90 kg ha^{-1}) and K_2O (0, 30, 60 and 90 kg ha^{-1}) were randomly distributed in three blocks of each strip along with three control ($N_0P_0K_0$) plots having seven treatments in each block with one control. Bentonite sulphur, single super phosphate and muriate of potash were used as a source of fertilizer S, P and K. Plot wise nutrient levels were tested before applying FYM and NPK. Available N, S, P and K status of soil were estimated using the chemical soil test methods (Subbiah and Asija (1956), (0.15% CaCl2 extractable-S William and Steinberg, 1959), Olsen *et al*. (1954) and ammonium acetate-K (CSTPA, 1974). Grain and straw samples at harvest were analyzed for total N, P and K as per the standard procedures. Using the data on grain yield, nutrient uptake, pre-sowing soil available nutrients and applied fertilizer doses, basic parameter, *viz*. nutrient requirement (kg q^{-1}), contribution of nutrients from soil and fertilizer sources were estimated as described by Ramamoorthy et al (1967).

RESULTS AND DISCUSSION

The data on soil test values of S, P and K; doses of fertilizer S, P and K nutrients; grain yield of soybean and chickpea and nutrient uptake were statistically analyzed. The significant soil test crop response correlations were obtained. Results indicate that the larger proportion of variation in grain yields of soybean and chickpea was accounted for by S and P. Application of fertilizer S and P explained the 88 % yield variation in soybean and 84 % yield variation in chickpea. Maximum yield variation recorded (92%) when all the three nutrients along with FYM were added. This indicates that FYM can enhanced the crop yield by added nutrients particularly fertilizer S and P (Table 3). Almost similar trends were seen with chickpea also. The range and mean values of available nutrients (S, P and K) (Table 1) indicate that soil test S, P and K varied with different fertility strips although soil test S and K variations with respect to fertility strip were marginal however, soil P variation in different fertility strips were quite marked and it increased across the fertility strips. Range and mean of soybean and chickpea

Table 1: Range and mean values of available S, P and K (kg ha-1) before *Kharif* season, 2013 with Soybean and before *rabi* season, 2013-14 with chickpea

Soil Nutrients	L0	L1	L2	SD	CV %
Before *kharif* season, 2013 with soybean (JS-9752)					
0.15% $CaCl_2$ extractable-S	18.78-38.95 (26.04)	19.27-36.66 (27.93)	21.52-39.79 (27.27)	4.81	17.87
Olsen's P	11.37-15.74 (13.15)	13.29-22.87 (17.78)	16.91-37.04 (26.98)	6.71	34.76
Amm. acetate extractable K	449.10-530.64 (476.82)	445.79- 543.30 (486.99)	446.51-525.89 (494.81)	24.69	5.08
Before *Rabi* season, 2013-14 with Chickpea (JG-130)					
0.15% $CaCl_2$ extractable-S	18.78-35.95 (25.38)	18.89-35.92 (27.38)	22.17-40.98 (28.10)	4.81	17.87
Olsen's P	11.00-17.67 (13.91)	13.40-24.56 (18.53)	18.76-39.93 (27.89)	6.81	33.86
Amm. acetate extractable K	433–537 (475)	437-544 (486)	438-529 (495)	27.88	5.74

(Values in parenthesis are average)

Table 2: Range and mean of grain yields of soybean and chick pea during *kharif and Rabi season*, 2013-14 in relation to fertility strips

Fertility strips	Grain yield (qha^{-1})			SD	CV%
	Minimum	Maximum	Average		
Kharif season, 2013 with Soybean (JS-9752)					
L0	14.8	30.68	25.35	4.83	19.04
L1	16.44	32.76	26.52	4.36	16.42
L2	15.24	33.80	27.00	4.45	16.48
All strips	14.80	33.80	26.29	4.54	17.26
Rabi season, 2013-14 with Chickpea (JG-130)					
L0	7.33	22.21	15.56	4.21	27.07
L1	9.09	22.44	16.39	3.81	23.23
L2	10.19	23.51	17.1	3.99	23.33
All strips	7.33	23.51	16.35	4.00	24.47

Table 3: Selected regression model to account for yield variation of soybean and chickpea

S.No.	Model for soybean General equation	R2
1	Y = 19.676 + 0.369FS	0.726
2	Y = 20.049 + 0.124FP	0.671
3	Y = 22.063 + 0.091FK	0.338
4	Y = 25.381 + 0.181FYM	0.027
5	Y = 18.162 + 0.245FS + 0.074FP	0.884
6	Y = 17.940 + 0.238FS + 0.068FP + 0.014FK	0.889
7	Y = 17.030 + 0.238FS + 0.068FP + 0.014FK + 0.181FYM	0.916
8	Y = 18.766 + 0.369FS + 0.181FYM	0.753
9	Y = 17.533 + 0.084SS + 0.361 FS	0.733
10	Y = 18.934 + 0.054SP + 0.125FP	0.677
11	Y = 19.194 + 0.487FS-0.003FS2	0.733
12	Y = 19.524 + 0.166FP–0.0004FP2	0.679
	Model for chickpea General equation	
13	Y = 10.758 + 0.312FS	0.667
14	Y = 10.837 + 0.110FP	0.674
15	Y = 12.702 + 0.078FK	0.328
16	Y = 15.840 + 0.102FYM	0.011
17	Y = 9.332 + 0.195FS + 0.070FP	0.848
18	Y = 9.164 + 0.189FS + 0.065FP + 0.011FK	0.852
19	Y = 8.640 + 0.188FS + 0.065FP + 0.011FK + 0.103FYM	0.863
20	Y = 10.248 + 0.312FS + 0.102FYM	0.678
21	Y = 9.934 + 0.035SS + 0.303FS	0.669
22	Y = 10.094 + 0.040SP + 0.108FP	0.678
23	Y = 11.384 + 0.158FS + 0.0049FS2	0.683
24	Y = 11.280 + 0.074FP + 0.00039FP2	0.681

Table 4: Nutrient requirement, Efficiencies of fertilizers nutrients, soil nutrients and FYM for soybean and chickpea

Parameters	Soybean			Chickpea		
	S	P	K	S	P	K
Nutrient Requirement	0.35	0.46	2.25	0.47	0.46	2.40
Fertilizer Efficiency (%)Ef	14.75	15.79	56.05	12.06	10.01	38.62
Soil Test Efficiency (%) Es	27.48	49.20	8.09	21.53	30.03	5.40
FYM Efficiency (%) Eorg	2.93	5.20	5.65	1.93	4.42	7.19

grain yield under different strips are given in Table 2. Maximum yield was obtained in strip III followed by strip II and lowest in strip I. Basic data to calculate the nutrient requirement for targeted yield of soybean and chickpea are given in table 4. The amount of nutrient required to produce one quintal of soybean grain was found to be 0.35 kg S, 0.46 kg P and 2.25 kg K. Similarly, 0.47 kg S, 0.46 kg P and 2.40 kg K were required to produce one quintal of grain production for chickpea. The fertilizer efficiencies of S, P and K for soybean crop were estimated as 14.75, 15.79 and 56.05 per cent, respectively. Similarly, the fertilizer efficiencies of S, P and K for chickpea crop were estimated as 12.06, 10.01 and 38.62 per cent, respectively. The efficiencies of soil test for soybean were recorded as 27.48 % S, 49.20% P and 8.09% K and that for chickpea were as 21.53 % S, 30.03 % P and 5.40 % K. While the efficiencies of organic source (FYM) were observed as 2.93, 5.20 and 5.65 for soybean and 1.93, 4.42 and 7.19 percent S, P, K for chickpea crop. These results indicated that nutrient contribution from fertilizer was greater than soil source. The findings are in closely accorded with those reported by Ramamoorthy *et al*. (1967), Suri and Verma (2000), Bera *et al*. (2006) Gautam *et al*. (2013) and Singh *et al*. (2014).

Table 5: Estimation of soil test based fertilizer recommendation for 20 and 25 q ha^{-1} grain yield target of soybean (var. JS-9752) crop with 5 tonnes FYM

Soil Test values(kg/ha)			Yield Target of soybean (q/ha)					
			20			25		
SS	SP	SK	FS	FP	FK	FS	FP	FK
8	4	200	32	45	52	44	59	72
10	6	225	28	38	48	40	53	68
12	8	250	25	32	45	37	47	65
14	10	275	21	26	41	33	41	61
16	12	300	17	20	38	29	34	58
18	14	325	14	13	34	26	28	54
20	16	350	10	7	31	22	22	51
22	18	375	6	1	27	18	16	47
24	20	400	2	0	24	14	9	44
26	22	425	0	0	20	11	3	40
28	24	450	0	0	17	7	0	37
30	26	500	0	0	10	3	0	30

Table 6: Estimation of soil test based fertilizer recommendation for 10, 12 and 14 q ha^{-1} grain yield target of chickpea (var.JG-130) crop with 5 tonnes FYM

Soil test values kg/ha			Yield Target of chickpea (q/ha)								
			10			12			14		
S	P	K	FS	FP	FK	FS	FP	FK	FS	FP	FK
8	4	200	24	32	33	32	41	46	39	50	58
10	6	225	20	26	30	28	35	42	36	44	55
12	8	250	17	20	27	24	29	39	32	38	51
14	10	275	13	14	23	21	23	35	29	32	48
16	12	300	10	8	20	17	17	32	25	26	44
18	14	325	6	8	16	14	11	29	21	20	41
20	16	350	6	8	13	10	5	25	18	14	37
22	18	375	6	8	9	7	5	22	14	8	34
24	20	400	6	8	6	3	5	18	11	2	31
26	22	425	6	8	6	3	5	15	7	2	27
28	24	450	6	8	6	3	5	11	4	2	24
30	26	500	6	8	6	3	5	4	4	2	17

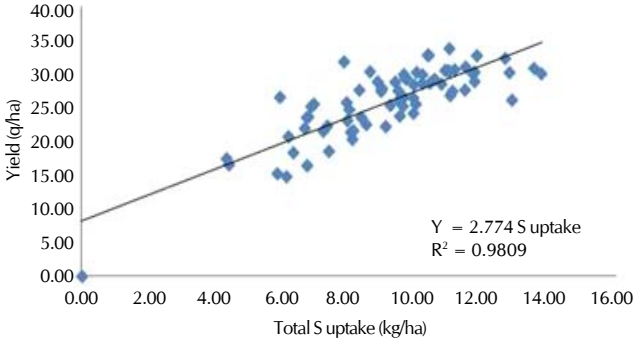

Figure 1: Relationship between soybean grain yield and total S uptake

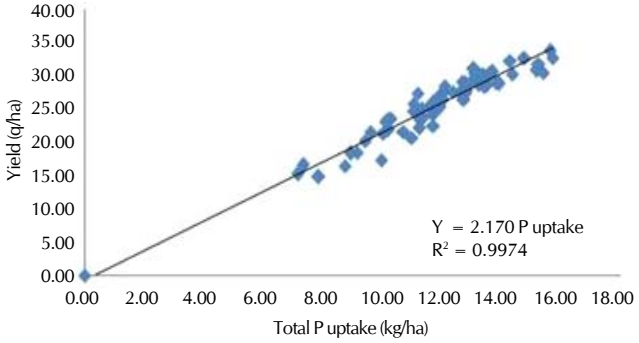

Figure 2: Relationship between soybean grain yield and total P uptake

Contribution from organic matter was low 2.93% S, 5.20% P and 5.65% K. These findings were in close conformity with those reported by Shiva Autar Mishra *et al*.(2015) Regar and Singh (2014), Singh and Singh *et al*. (2014) and Singh *et al*.(2014).

By using these basic parameters, targeted yield equation for soybean and chickpea crop was developed with respect to fertilizer sulphur, phosphorus and potassium requirement (kg ha^{-1}). The equations are as follows:

Fertilizer prescription equation for Soybean

FS = 2.40Y - 1.86 SS - 0.20 FYM

FP = 2.94Y - 3.12 SP - 0.33 FYM

FK = 4.01Y - 0.14 SK - 0.10FYM

Fertilizer prescription equation for chickpea

FS = 3.89Y - 1.79 SS - 0.16 FYM

FP = 4.60Y - 3.00 SP - 0.44 FYM

FK = 6.22Y - 0.14 SK - 0.19 FYM

Where, FS, FP and FK are fertilizer S, P2O5 and K2O (kg ha -1)

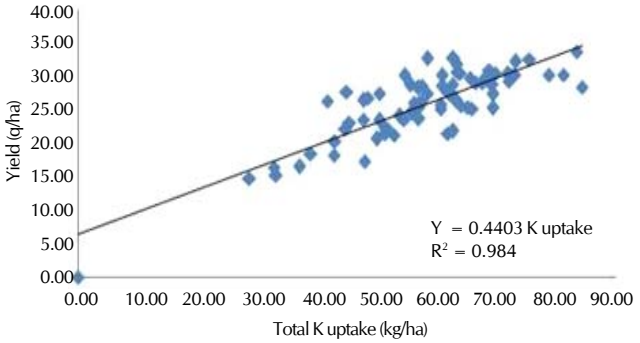

Figure 3: Relationship between soybean grain yield and total K uptake

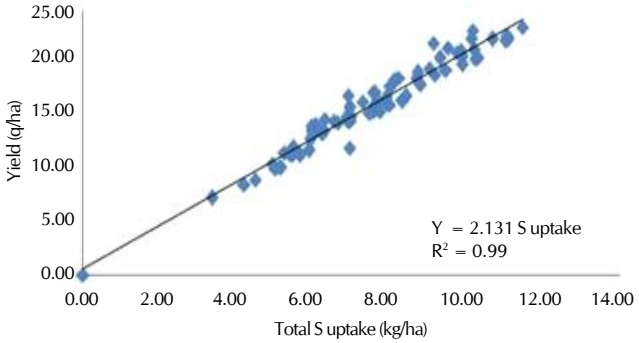

Figure 4: Relationship between chickpea grain yield and total S uptake

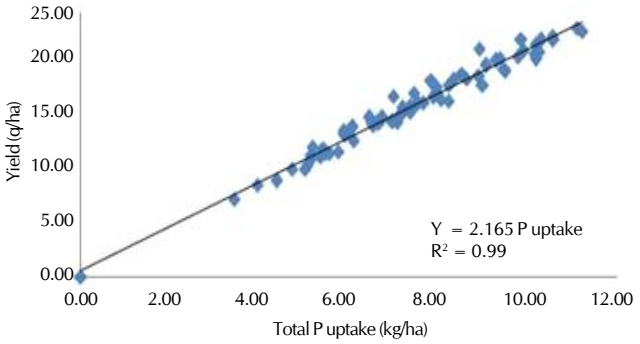

Figure 5: Relationship between chickpea grain yield and total P uptake

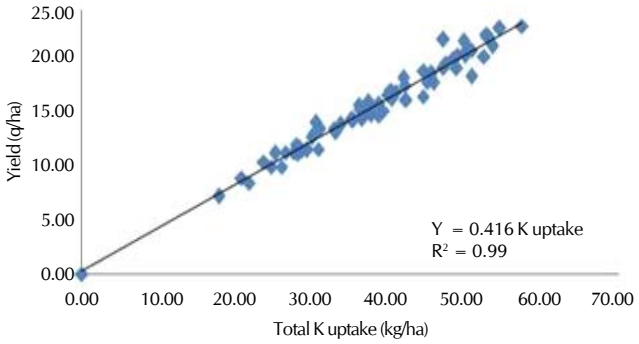

Figure 6: Relationship between chickpea grain yield and total K uptake

respectively. FYM is Farm Yard Manure (t ha-1). SS, SP and SK are soil test values (kg ha-1) for, 0.15% CaCl2 extractable-S William and Steinberg , Olsen's P and ammonium acetate extractable-K and Y is crop yield in q ha^{-1}. Such kind of fertilizer prescription equations for different crops (rice, wheat, maize, mustard, rapeseed) have also been documented by Shiva Autar Mishra *et al*.(2015), Regar and Singh (2014), Mahajan *et al*.(2013), Milapchand *et al*. (2006).

Soil test based fertilizer doses required for soybean and chickpea grain yield target of 20 and 25 q ha^{-1}, and 10, 12 and 14 q ha^{-1} respectively for varying soil test values of S, P and K are reported in table 5 and 6. A perusal of the data indicated that the dose of fertilizer nutrients decreased for each nutrient increase in soil test values. This is the main advantageous component in the soil test based fertilizer application employing targeted yield equations over other approaches of the fertilizer recommendations in which soils are categorized into low, medium and high categories and accordingly the doses of fertilizer nutrients are recommended. Fertilizer recommendations based on this concept are more quantitative, precise and meaningful because combined use of soil and plant analysis is involved in it. Thus, it provides the scientific basis for balanced fertilization. It is also advantageous to the farmer that he can choose his target according to his resource and management conditions. Currently this technology is being focused through frontline demonstration in different locations at farmer's fields which revealed that benefit : cost ratio was found to be much higher in case of fertilizer treatments based on this methodology as compared to the fertilizer doses based on general recommended dose or local farmer's practice (Velayutham *et al.,* 1985; Sharma and Singh, 1999; Ray *et al.,* 2000; Reddy and Ahmed, 2000; Verma *et al.,* 2005; Gogoi *et al.,* 2011).

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