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Validation of Soil Test and Yield Target Based Balanced Fertilizer Prescription Model for Glory Lily on Alfisol

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A B S T R A C T

Soil Test Crop Response based fertilizer prescription equations for desired seed yield target of glory lily were developed under Integrated Plant Nutrition System (STCR-IPNS) on Typic Rhodustalf (Palaviduthi soil series) of Tamil Nadu. On farm testing of STCR-IPNS equations are essential to demonstrate the effectiveness of technology to the clients. The present study was undertaken to evaluate the targeted yield model through field experiments at six locations in Dindigul district, Southern zone of Tamil Nadu. The treatments include control, blanket recommendation (RDF alone), soil test crop response (STCR) based fertilizer dose for the seed yield targets of 5.5, 6.5 and 7.5 q ha^{-1}, STCR-IPNS based fertilizer dose for the seed yield targets of 5.5, 6.5 and 7.5 q ha^{-1} and farmer's practice. Results elucidated that in all the six locations, the per cent achievement of the targeted yield was within ± 10 per cent variation proving the validity of the equations for prescribing integrated fertilizer doses for glory lily. The highest mean seed yield was recorded in STCR-IPNS – 7.5 q ha^{-1} (725 kg ha^{-1}) recording an increase of 43.19 per cent over blanket recommendation. The highest response ratio and B:C ratio of 0.78 and 1.72 respectively were recorded in the yield target of 7.5 q ha^{-1} under STCR-IPNS. The post-harvest soil available NPK indicated the built up and maintenance of soil fertility due to soil test based fertilizer recommendation under IPNS. The fertilizer prescription equations developed for glory lily under IPNS can be recommended for red non calcareous soils of Tamil Nadu for achieving the yield target of 7.5 q ha^{-1} with sustained soil fertility and it can be extrapolated to other agro-climatic zones of Tamil Nadu on similar and allied soil types.

Introduction

Soil test based precised fertiliser prescription is essential for achieving higher crop productivity with sustained soil health. Besides the yield increase and fertiliser consumption, achievement in fertiliser use efficiency among the Indian farmers is

lacking. Escalation in cost, non uniform distribution, non availability of fertilizers at times etc. are found to be the major causes of imbalanced nutrient supply that led to stagnated productivity and steep reduction in soil health. Poor supply of organic manures, change in the cropping pattern, low productivity of indigenous milk animals, introduction of exotic breeds for milking etc. are very common in the semi arid tropics like India. In the present scenario, either solely with inorganic fertilizers or organic sources is practically not possible. However, nutrient removal by crops far exceeds nutrient additions through fertilizers. An annual net negative balance of about 8-10 million tons of nutrients is reported in India (Tandon, 2007). Deterioration in soil health due to indiscriminate and imbalanced use of fertilizers, can be corrected and sustenance of soil health is possible only when fertilizers are prescribed based not only on soil testing but also with integrated use of possible organic sources with inorganic fertilizers.

Glory lily (*Gloriosa superba* Linn.), the state flower of Tamil Nadu is an important medicinal crop belonging to the family Liliaceae. It is extensively scattered in the tropical and sub-tropical parts of the India with different soil type and climate. In the world market, glory lily has been considered as rich source of colchicine and gloriosine. It is one of the major medicinal crops cultivated in India for its seeds which are exported to developed countries for pharmaceutical use. In Tamil Nadu, medicinal and aromatic plants cultivated in an area of 10,038 ha in 2018. Among the medicinal plants, Gliosa superba cultivation occupies 3,336 hectares (http://www.imotforum.com/2020/05/does-glory-lily-cultivation-brings-glory-to-tn-farmers/).

Wide variations were noticed in fertiliser recommendations for glory lily. Results of the field experiments under Bangalore conditions have shown that a fertiliser dose of 120 kg N, 50 kg P_2O_5 and 75 kg K_2O ha^{-1} is required for a good crop (Farrooki and Sreeramu, 2004 and Purohit and Vyas, 2004). Vasanthi (2012) optimized the fertiliser dose of 150:50:100 kg N, P and K ha^{-1} for glory lily tracts of Tamil Nadu. In conventional method, blanket recommendation is prescribed without considering the contribution from soil and a blanket dose of 120:50:75 kg of NPK ha^{-1}, is being followed in Tamil Nadu (CPG, 2020). The targeted yield approach (Ramamoorthy *et al.*1967) provides the scientific basis for balanced fertilization which in turn gives a real balance between applied nutrients and the available nutrients already present in the soil.

Fertiliser prescription equations have been developed for medicinal crops like ashwagandha (Santhi *et al.,* 2010) and glory lily (Sellamuthu *et al.,* 2015a) (under IPNS based on this concept.

To reap the maximum benefit, enhanced nutrient use efficiency and reduced nutrient losses, fertilizers must be applied in the right quantity, from the right sources and in the right combination at the right time using the right methods (Dey, 2015; Singh, 2016). In the present context of popularization of medicinal crops like glory lily, it is essential to develop fertiliser prescription equations for getting maximum yield and sustaining soil fertility. Hence, the present study was undertaken for glory lily on Typic Rhodustalf (Palaviduthi soil series) in Southern Zone of Tamil Nadu with an aim to validate the developed equation for maximising the productivity of glory lily.

Materials and Methods

To validate the fertilizer prescription equations developed for glory lily under IPNS on Typic Rhodustalf (Palaviduthi soil series)

in Southern zone of Tamil Nadu, six verification trials were conducted during 2014-16 at C.K. Valasu I and II, Chinnamandavadi I and II, Kappalpatty I and II of Dindigul district. Initial soil samples were collected from each location and analyzed for pH, E.C, alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al.*, 1954), NH_4OAc-K (Stanford and English, 1949) and DTPA extractable micronutrients (Lindsay and Norwell, 1978). The initial soil fertility status for different locations is shown in Table 1. Fertilizer prescription equations developed for glory lily under IPNS on Palaviduthi soil series are furnished below:

FN = 41.45 T - 0.53 SN – 0.71 ON
FP2O5 = 23.08 T - 1.92 SP - 0.88 OP
FK2O = 30.45 T - 0.21 SK - 0.64 OK

where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1} respectively;

T = Seed yield target in q ha^{-1}; SN, SP and SK are available N, P and K in kg ha^{-1} respectively; ON, OP and OK are N, P and K supplied through FYM in kg ha^{-1}

The treatments imposed are control, blanket fertilizer dose, STCR based fertilizer dose for the seed yield target of 5.5, 6.5 and 7.5 q ha^{-1}, STCR-IPNS based fertilizer dose for the seed yield target of 5.5, 6.5 and 7.5 q ha^{-1}, and farmers practice. Based on the initial soil test values of available N, P and K and the quantities of N, P_2O_5 and K_2O supplied through FYM, fertilizer doses were calculated and applied for STCR treatments for various yield targets. STCR-NPK alone treatments received only inorganic fertilizers based on STCR equations developed, where as for IPNS treatments receiving (NPK+ FYM @ 12.5 t ha^{-1}), fertilizers were applied after adjusting the nutrients supplied through FYM based on STCR-IPNS equations (Table 2). Full dose of FYM, half of N and full dose of P_2O_5 and K_2O were applied basally. Remaining half of N was applied after 30 and 60 days of sprouting of tubers and all other packages of practices were carried out periodically.

The crop was grown to maturity and the seed yield was recorded plot wise. Using the data on seed yield and fertilizer doses applied, the parameters *viz*., per cent achievement {(yield obtained / yield target aimed) x 100} and response ratio (RR) were worked out (Response Ratio = Response in kg ha^{-1} / Quantities of fertilizer N, P_2O_5 and K_2O applied in kg ha^{-1}). B:C ratio was worked out based on the price of the produce and cost incurred for the cultivation as per the standard procedure. Statistical analysis was carried out using Agres Package considering each location as one replication with randomised block design. Post-harvest soil samples were collected and analyzed for available N, P and K status.

Results and Discussion

Seed yield of glory lily

The data on pooled mean seed yield of six locations revealed that the highest seed yield was recorded in the treatment STCR-IPNS-7.5 q ha^{-1} (725 kg ha^{-1}) followed by STCR-NPK alone -7.5 q ha^{-1} (710 kg ha^{-1}) indicating that the STCR -IPNS treatments recorded relatively higher yield over STCR -NPK alone treatments (Table 3 and Fig. 1). STCR -IPNS-7.5 q ha^{-1} recorded an yield increase of 43.19 per cent over blanket recommendation (506 kg ha^{-1}) followed by STCR -NPK-7.5 q ha^{-1} (40.13 per cent). Statistical scrutiny of yield data from the six locations revealed that STCR -IPNS-7.5 q ha^{-1} found to record significantly higher seed yield and it was on par with STCR NPK-7.5 q ha^{-1} whereas blanket recorded significantly lower yield over STCR treatments.

Table.1 Initial soil fertility status of the field experiments

Sl. No	Locations	pH	E.C (dSm^{-1})	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	Zn ($mg\ kg^{-1}$)	Fe ($mg\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	Cu ($mg\ kg^{-1}$)
1.	C.K. Valasu I	**8.15**	**0.26**	172	21.4	260	0.86	3.60	6.46	0.58
2.	Chinnamandavadi I	**7.35**	**0.25**	224	26.4	320	0.65	4.80	9.56	0.64
3.	C.K. Valasu II	7.23	0.13	203	20.2	240	0.82	4.20	8.42	0.82
4.	Chinnamandavadi II	7.62	0.12	178	27.5	266	0.54	4.60	12.4	0.68
5.	Kappalpatty I	**6.59**	**0.34**	193	14.0	179	1.02	5.20	8.60	0.65
6.	Kappalpatty II	**6.60**	**0.38**	186	16.0	182	0.96	4.68	7.62	0.86

Table.2 Fertilizer doses ($kg\ ha^{-1}$) imposed in six locations based on fertilizer prescription equation

S. No.	Treatments	C.K. Valasu I 2014-15			Chinnamandavadi I 2014-15			C.K. Valasu II 2014-15			Chinnamandavadi II 2014-15			Kappalpatty I 2015-16			Kappalpatty II 2015-16		
		N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	**K**
1.	Blanket	150	50	100	150	50	100	150	50	100	150	50	100	150	50	100	150	50	**100**
2.	STCR - NPK alone – 5.5 q ha^{-1}	137	86	113	109	76	100 **	120	88	117	134	74	112	126	100 **	130	129	96	**129**
3.	STCR - NPK alone – 6.5 q ha^{-1}	178	100 **	143	151	99	131	162	100 **	148	175	97	142	167	100 **	160	171	100 **	**160**
4.	STCR - NPK alone – 7.5 q ha^{-1}	220	100 **	174	192	100 **	161	203	100 **	178	217	100 **	173	209	100 **	191	212	100 **	**190**
5.	STCR - IPNS – 5.5 q ha^{-1}	102	64	83	75*	54	70	85	66	87	99	52	82	91	78	100	94	74	**99**
6.	STCR - IPNS – 6.5 q ha^{-1}	143	87	113	116	77	101	127	89	118	140	75	112	132	100 **	130	136	97	**130**
7.	STCR - IPNS – 7.5 q ha^{-1}	185	100 **	144	157	100 **	131	168	100 **	148	182	98	143	174	100 **	161	177	100 **	**160**
8.	Farmers Practice	96	50	76	86	42	70	92	48	72	102	51	78	88	59	104	94	48	**93**
9.	**Control**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

IPNS=NPK+FYM @ 12.5 t ha^{-1} *maintenance dose **maximum dose

Table.3 Seed yield, RR, % achievement and B:C ratio of glory lily

S. No.	Treatments	Seed Yield (kg ha^{-1})							* % Yield increase over blanket	*RR (kg kg^{-1})	*Per cent Achievement	*B:C Ratio
		C.K. Valasu I 2014-15	Chinnam andavadi I 2014-15	C.K. Valasu II 2014-15	Chinnam andavadi II 2014-15	Kappalpatty I 2015-16	Kappalpatty II 2015-16	Pooled Mean				
1.	Blanket	478	496	504	510	532	518	506	-	0.53	-	**1.22**
2.	STCR - NPK alone – 5.5 q ha^{-1}	538	524	526	538	558	546	538	6.32	0.59	97.88	**1.30**
3.	STCR - NPK alone – 6.5 q ha^{-1}	644	646	642	639	635	640	641	26.60	0.71	98.63	**1.54**
4.	STCR - NPK alone – 7.5 q ha^{-1}	649	650	730	740	746	742	710	40.13	0.75	94.60	**1.68**
5.	STCR - IPNS – 5.5 q ha^{-1}	558	546	540	560	568	566	556	9.87	0.64	101.17	**1.34**
6.	STCR - IPNS – 6.5 q ha^{-1}	656	658	656	674	670	660	662	30.81	0.77	101.88	**1.59**
7.	STCR - IPNS – 7.5 q ha^{-1}	662	661	745	760	764	758	725	43.19	0.78	96.67	**1.72**
8.	Farmers Practice	456	462	460	486	480	465	468	-	0.55	-	**1.14**
9.	Control	316	330	310	328	396	402	347	-	0.53	-	**0.85**
	SEd				**13.1**				**-**	**-**	**-**	**-**
	CD(.05)				**26.4**							

*Mean values for six field experiments

Table.4 Post- harvest soil fertility as influenced by various treatments

S. No.	Treatments	C.K. Valasu I 2014-15			Chinnamanda-vadi I 2014-15			C.K. Valasu II 2014-15			Chinnamanda-vadi II 2014-15			Kappalpatty I 2015-16			Kappalpatty II 2015-16		
		SN	SP	SK	SN	SP	SK	SN	SP	SK	SN	SP	SK	SN	SP	SK	SN	SP	**SK**
		kg ha^{-1}																	
1.	Blanket	170	22.9	255	220	28.5	317	195	21.8	238	176	30.3	261	189	15.3	174	184	17.3	**180**
2.	STCR - NPK alone – 5.5 q ha^{-1}	187	26.8	274	237	32.9	339	215	25.3	253	193	33.8	281	205	17.6	190	195	20.0	**192**
3.	STCR - NPK alone – 6.5 q ha^{-1}	198	29.3	281	253	35.6	342	229	27.3	260	205	37.8	287	218	18.9	195	209	21.8	**198**
4.	STCR - NPK alone – 7.5 q ha^{-1}	201	30.0	286	262	37.0	350	235	28.3	263	208	38.2	293	226	19.9	197	216	22.4	**200**
5.	STCR - IPNS – 5.5 q ha^{-1}	194	27.2	275	251	33.3	338	227	25.5	252	200	35.1	281	216	17.5	189	208	20.2	**191**
6.	STCR - IPNS – 6.5 q ha^{-1}	205	31.2	296	264	39.6	358	240	30.3	269	212	40.2	303	228	20.9	201	218	24.0	**204**
7.	STCR - IPNS – 7.5 q ha^{-1}	210	34.5	304	269	42.2	378	244	32.3	283	217	44.0	311	232	22.7	212	225	25.6	**215**
8.	Farmers Practice	167	21.8	268	222	28.0	323	199	20.6	250	174	28.6	274	189	14.6	186	184	17.1	**184**
9.	Control	162	20.5	252	213	25.1	314	193	18.6	238	171	26.1	258	185	13.6	174	177	15.2	**178**
	Initial values	**172**	**21.4**	**260**	**224**	**26.4**	**320**	**203**	**20.2**	**240**	**178**	**27.5**	**266**	**193**	**14.0**	**179**	**186**	**16.0**	**182**

Fig.1 Effect of treatments on seed yield of glory lily in six locations

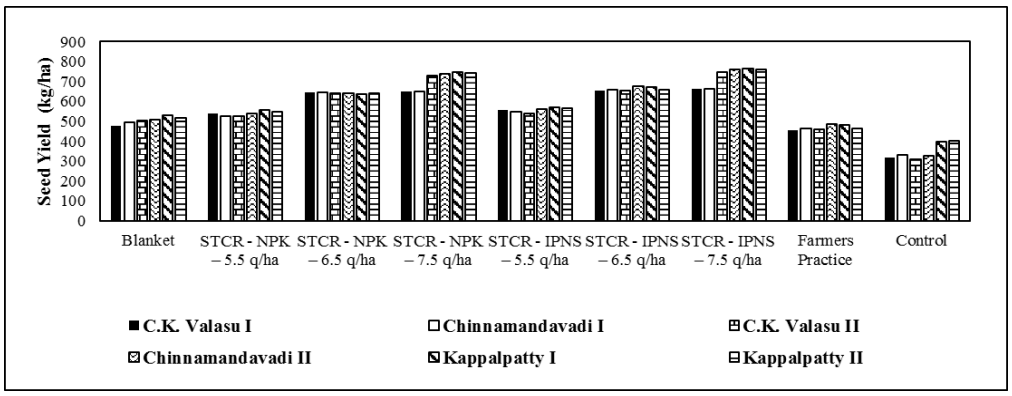
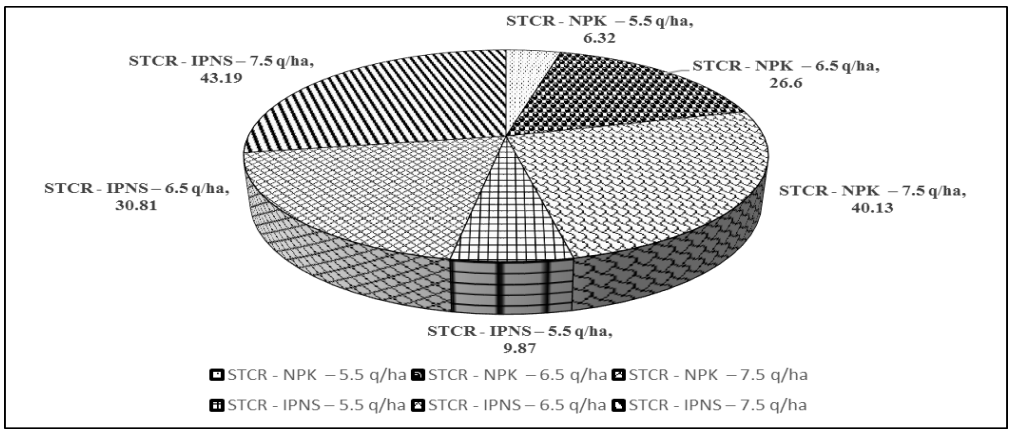


Fig.2 Effect of treatments on per cent increase in seed yield of glory lily over blanket



Similar findings indicated that application of inorganic fertilizer along with organic manures recorded higher seed and straw yield (Kaleeswari *et al.,* 2011). This could also be due to the integrated use of organic manures with chemical fertilizers which could have resulted in increased available nutrient status over sole use of chemical fertilizers (Kaleeswari *et al.,* 2011; Shah *et al.,* 2013; Sellamuthu *et al.,* 2015b and 2016) and ultimately due to higher uptake (Sathish *et al.,* 2011) and increased use efficiency of nutrients (Jat *et al.,* 2014) (Fig. 2).

Percent achievement, RR and cost benefit ratio

The highest per cent achievement of the yield target was recorded with STCR-IPNS-6.5 q ha^{-1} (101.88) followed by STCR-IPNS-5.5 q ha^{-1} (101.17) (Table 3). Yield targeting with IPNS recorded relatively higher per cent achievement than that aimed under their respective NPK alone treatments. Sujatha *et al.,* (2008) reported similar results of positive effects of combination of sunhemp green manuring, use of biofertilizers and compost with inorganic fertilizers on growth and yield of rainfed maize. In all the six verification trials, the per cent achievement of the targeted yield was within ±10 per cent variation proving the validity of the equations for prescribing integrated fertilizer doses for glory lily. STCR-IPNS technology ensures sustainable crop production with economical use of fertilizer inputs (Mahajan *et al.,* 2013). The mean RR recorded for various treatments ranged from 0.53 kg kg^{-1} in blanket to 0.78 kg

kg^{-1} in STCR-IPNS-7.5 q ha^{-1} (Table 3). Among the STCR treatments, IPNS recorded relatively higher RR than NPK alone due to the better use efficiency of applied fertilizers under IPNS. Balanced supply of nutrients from fertilizer, efficient utilization of applied fertilizer nutrients in the presence of organic sources and the synergistic effect of the conjoint addition of various sources of nutrients resulted in relatively higher RR recorded under STCR and STCR-IPNS treatments when compared to blanket recommendation. The results are corroborated with the findings of Muralidharudu *et al.,* (2011) and Dey and Das (2014). STCR-IPNS-7.5 q ha^{-1} was found to record the highest B:C ratio of 1.72. (Table 3) which was in close conformity with the findings reported by Sujatha *et al.,* (2008), Kalhapure *et al.,* (2013) and Sellamuthu *et al.,* (2015b and 2016).

Post harvest soil fertility

Soil available N ranged from 162 to 210 kg ha^{-1} at C.K.Valasu I, 213 to 269 kg ha^{-1} at Chinnamandavadi I, 193 to 244 kg ha^{-1} at C.K.Valasu II, 171 to 217 kg ha^{-1} at Chinnamandavadi II, 185 to 232 kg ha^{-1} at Kappalpatty I and 177 to 225 kg ha^{-1} at Kappalpatty II (Table 4). In all the locations, the higher available N was recorded in STCR-IPNS treatments followed by STCR-NPK alone. When compared with the initial soil fertility, control, farmers practice and blanket, recorded reduction in available N but the degree of reduction was less in blanket (Sellamuthu *et al.*, 2016)

Soil available P ranged from 20.5 to 34.5 kg ha^{-1} at C.K.Valasu I, 25.1 to 42.2 kg ha^{-1} at Chinnamandavadi I, 18.6 to 32.3 kg ha^{-1} at C.K.Valasu II, 26.1 to 28.6 kg ha^{-1} at Chinnamandavadi II, 13.6 to 22.7 kg ha^{-1} at Kappalpatty I and 15.2 to 25.6 kg ha^{-1} at Kappalpatty II (Table 4). STCR-IPNS treatments recorded higher available P in all the locations followed by STCR-NPK alone treatments and blanket while control and farmers practice recorded lower available P (Sellamuthu *et al.,* 2016)

Soil available K ranged from 252 to 304 kg ha^{-1}, 314 to 378 kg ha^{-1}, 238 to 283 kg ha^{-1}, 258 to 311 kg ha^{-1}, 174 to 186 kg ha^{-1}, 178 to 215 kg ha^{-1} at C.K.Valasu I, Chinnamandavadi I, C.K.Valasu II, Chinnamandavadi II, Kappalpatty I and Kappalpatty II (Table 4). Higher available K was recorded in STCR-IPNS treatments in all the locations followed by STCR-NPK alone treatments while control and farmers practice recorded lower available K. The degree of reduction was higher in control and farmers practice when compared to the initial soil fertility while in blanket reduction in available K was less (Sellamuthu *et al.*, 2016)

Post harvest soil fertility values of $KMnO_4$-N, Olsen-P and NH_4OAc-K indicated the built up and maintenance of soil fertility due to soil test based fertilizer recommendation under IPNS. Despite higher removal of nutrients, the fertility status was maintained in STCR-IPNS as compared to STCR-NPK alone (Table 4). This could be due to the prevention of losses of nutrients under IPNS, even after meeting the crop needs. Application of farm yard manure in conjunction with chemical fertilizers not only increases the productivity but also improve the soil fertility (Jaga and Upadhyay, 2013). The targeted yield concept provides rational and increased fertilizer use and reduce the fertilizer requirements if it is combined with FYM (Velayutham *et al.,* 2016).

In conclusions the per cent achievement of the targeted yield of all the six validation experiments was within ±10 per cent variation proving the validity of the equations for prescribing balanced fertilizer doses for glory lily to achieve the seed yield target of 7.5 q

ha^{-1} with higher RR, per cent achievement and benefit cost ratio. The post-harvest soil available N, P and K status indicated the built up and maintenance of soil fertility due to soil test based fertilizer prescription under IPNS. Hence, the fertilizer prescription equations developed for glory lily under IPNS can be recommended for red non- calcareous soils (Typic Rhodustalf - Palaviduthi soil series) of Tamil Nadu for achieving yield target of 7.5 q ha^{-1} with sustained soil health.

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