

Effect of improved nutrient management on grain yield of rice (*Oryza sativa*) and soil health under organic management

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ABSTRACT

A field experiment was conducted at ICAR Research Complex for Goa, Goa, for 5 years during 2009–13, to standardize different nutrient sources for organic production in 3 varieties of rice (*Oryza sativa* L.) in split-plot design with 3 replications. Rice variety 'Karjat 3' gave significantly higher grain yield (4.09 t/ha) than either 'Revathy' (3.49 t/ha) or 'Pusa Sugandh 5' (2.47 t/ha). Application of FYM resulted in at par grain yield (3.66 t/ha) with recommended fertilizers (3.87 t/ha), while *Gliricidia* with *Eupatorium* sp. recorded 90% of the grain yield (3.47 t/ha) and 86% of the straw yield (6.88 t/ha) obtained with recommended fertilizers (3.87 and 7.99 t/ha, respectively). Higher increase in soil organic carbon was observed with the application of FYM over 5 years (1.24%). Levels of P and K in the soil were appreciably reduced after 5 rice crops with the application of any of the nutrient sources. Application of vermi-compost influenced higher buildup of both bacterial and actinomycetes growth in soil (24.72×10^5 CFU/g and 53.39×10^4 CFU/g, respectively). Application of *Gliricidia* with *Eupatorium* sp. recorded at par net returns (₹40,000/ha) by recording 96.5% net returns of the recommended fertilizers (₹41,460/ha).

Key words : Grain yield, Net returns, Organic nutrient sources, Recommended fertilizers, Rice, Soil fertility

Production technology for organic rice primarily involves 3 management practices—efficient crop management, appropriate nutrient management and effective plant-protection measures. To mitigate the increasing cost of production and to enhance the returns by the farmer, ensuring higher price with the quality rice is essential. This is because, the price premiums vary widely with different varieties especially in organic rice. Red kernelled, medium bold-grain-type is preferred for parboiling in the region, while the scented fine grain rice fetches higher price in the market owing to its grain quality. As such, identification of rice varieties for their suitability or otherwise in organic production is also essential (Manjunath *et al.*, 2012).

Various organic nutrient sources are available which contain good amount of major plant nutrients, NPK to produce comparable yield (Ghosh, 2005). The practices of organic cultivation vary with the availability of local manurial resources and their nutrient content and as such

it is necessary to identify both the source and its quantity to meet the nutrient requirement of rice. Farmyard manure (FYM), compost and green manures are the traditional sources of nutrients. Weeds are possible sources of organic manure; they are usually as rich in nutrients as or richer than many green manures. However, their high water content has been the major deterrent to the commercial use of aquatic weeds.

Further, the long-term impact on soil and the sustainability of the returns assumes major significance for large-scale adoption. As such, field trials were conducted to identify locally available manurial resources including weeds as nutrient sources and their impact on soil in 3 varieties of rice under west coast situations of India.

MATERIALS AND METHODS

A field experiment was conducted for 5 years from 2009 to 2013 at ICAR Research Complex for Goa, Old Goa, (15°30' N, 73°55' E and 16 m above mean sea-level) having humid tropical climate. The trials were conducted in fixed plot, consisting of 3 prominent rice types, viz. red-kernelled 'Revathy', a selection released from RARS, Moncompu, KAU, Kerala; scented 'Pusa Sugandh 5'—a semi-dwarf, high-yielding aromatic rice variety selection,

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and high-yielding, medium-duration rice 'Karjat 3' released from Dr BSKKV, Dapoli, as main plot treatments. The sub-plot treatments included 7 sources of nutrients, viz. farmyard manure, vermicompost, *Gliricidia* + *Eupatorium* sp., paddy straw + water hyacinth, *Sesbania rostrata*, recommended fertilizers and the control under rainfed conditions in a split-plot design with 3 replications.

Before field experimentation, the soil had pH 6.01 with an organic carbon content of 0.58%. The soils were lateritic and low in available N (154.9 kg/ha) and medium in P (9.2 kg/ha) and K (156 kg/ha). Transplanting of rice was done at a spacing of 20 cm × 10 cm. The crop was managed with recommended package of practices except for nutrition which was as per treatments during all the 5 years. A dose of 100, 50 and 50 kg N, P and K/ha was applied for recommended fertilizer plot after thorough bunding on all the 4 sides of the plot. Entire P and K and 50% of N was applied basal and another 50% N during panicle-initiation stage. The nutrient sources were selected based on the local availability and the quantity was determined based on equivalent N basis. The nutrient content of the different manurial resources used in the experiments were estimated based on standard procedures and the mean is given in Table 1. All the manurial resources were applied before planting and incorporated into the soil. Care was taken to ensure the non-movement of the organic manurial resources/ fertilizers from plot to plot by raising the field bunds for sufficient height.

Table 1. Mean nutrient content of the organic manurial resources used in the experiment (on dry-weight basis)

Nutrient source	N (%)	P ₂ O ₅ (%)	K ₂ O (%)
FYM	1.10	0.85	0.33
Vermi-compost	1.59	1.01	0.25
<i>Gliricidia</i>	4.13	0.45	1.85
<i>Eupatorium</i> sp.	2.52	0.05	1.58
Paddy straw	1.68	0.05	0.45
Water hyacinth	3.51	0.23	3.33
<i>Sesbania rostrata</i>	3.79	0.04	0.90

The relevant growth and yield parameters were recorded in rice and the data were analyzed using standard statistical procedures during all the years (Gomez and Gomez, 1984). The soil samples were collected after the rice crop each year, both for soil fertility parameters and the microbial count, and were analyzed as per the standard procedures. The economics was worked out based on the prevailing prices in the market during the period both for input and the outputs.

RESULTS AND DISCUSSION

Nutrient content of organic manurial sources

Among the nutrient sources, *Gliricidia* recorded higher content of all the 3 major nutrients (4.13, 0.45 and 1.85% N, P₂O₅ and K₂O respectively on dry-weight basis). The N content was also better both in *Sesbania rostrata* (3.79%) and water hyacinth (3.51%), the latter also recording higher K₂O (3.33%). The phosphorus content was more in vermi-compost (1.01%) and was followed by FYM (0.85%). The higher nutrient content of the organic manurial sources indicate their potential as good sources of nutrients. Early decomposing nature of *Gliricidia* with faster mineralization and release of nutrients made this leguminous crop a better source of major nutrients. Further, these organics also supply micronutrients like copper, zinc and manganese (Surekha *et al.*, 2008).

Growth and yield attributes

The pooled mean results indicated that among the rice varieties, 'Karjat 3' recorded significantly higher productive tillers, panicles, spikelets and harvest index, owing to better ideotype of the plant showing its supremacy to either red kernelled rice 'Revathy' or scented rice 'Pusa Sugandh 5' (Table 2). Although the plant height, total dry-matter production and panicle length were higher in 'Pusa Sugandh 5', it also recorded higher sterility.

Different manurial sources on a pooled mean basis showed a significant impact on the growth and yield parameters of rice. Recommended fertilizer application in general recorded higher growth and yield parameters which may be owing to the availability of all the 3 major nutrients in required quantities for the rice crop. Paddy straw application with water hyacinth recorded at par plant height with recommended fertilizers which may be owing to higher nitrogen content of the water hyacinth (on dry-weight basis) that encourages higher vegetative growth (Sridhar *et al.*, 2011). *Gliricidia* with *Eupatorium* sp. application showed significantly more productive tillers, dry-matter production and panicles. It is pertinent to note that application of FYM as well as *Gliricidia* with *Eupatorium* sp. recorded higher harvest index, even better than recommended fertilizers. The results indicate that organic sources like FYM, *Gliricidia* and *Eupatorium* sp. offered better nutritional quality and favourable balance of nutrients including micro-nutrients and the nutrient availability due to microbial action is slow and steady than in the case of fertilizers, which resulted in better yield as was also observed earlier by Rakshit *et al.*, (2008). Further, recommended fertilizer application resulted in relatively higher sterility, showing the importance of organic sources. Paude and Upasena (1996) also inferred that application of green leaf manure to meet 120 kg N/ha from

both *Leucaena* and *Glyricidia* gave yield and agronomical components of rice similar to that obtained from N at 60 kg/ha from urea with 19 to 49% increase in yields of rice. A positive correlation with grain yield in components of effective tillers/hill, filled grains/panicle, 1,000-grain weight, panicles/m², biomass and the straw yield was observed.

The interaction between rice varieties and nutrient sources was found significant especially for productive tillers and dry matter production. Rice variety 'Karjat 3' under recommended fertilizers application recorded significantly higher productive tillers (9.47/hill) owing to its genetic potential while 'Pusa Sugandh 5' recorded more total dry-matter production under FYM, *Gliricidia* with *Eupatorium* sp. and recommended fertilizers.

Grain and straw yields

Pooled mean results of the study indicated that rice variety 'Karjat 3' gave significantly higher grain yield than either 'Revathy' or 'Pusa Sugandh 5'. The higher yield in rice variety 'Karjat 3' may be attributed to significantly more number of productive tillers resulting in higher panicle number per unit area coupled with more spikelets in the panicle. In a study conducted by Huang *et al.* (2011), it was observed that panicles/m² showed the highest positive contribution to grain yield which need to be emphasized in rice production. The better plant ideotype of 'Karjat 3' was also reflected through higher harvest index in the variety with only moderate straw yield. On the

contrary, 'Pusa Sugandh 5' was although better in grain quality (with long slender grains) could record a grain yield of only 2.47 t/ha, its straw yield being higher than that of both 'Karjat 3' and 'Revathy'. The higher straw yield with 'Pusa Sugandh 5' could be attributed to the tall stature of the variety with higher biomass production as reflected through increased dry-matter production.

Further, the rice variety 'Karjat 3' recorded higher sustainability yield index significantly differing from 'Revathy' in the grain yield, although the varieties recorded non-significant differences as regards straw yield, showing the supremacy of the former for sustained rice grain yield.

Different sources of nutrients impacted the 5 years pooled mean grain yield of rice significantly as compared to the control, inferring that there is a scope for their selection for better yield realization (Table 3). Application of FYM resulted in at par grain yields with recommended fertilizers, recording nearly 95% of latter's yield showing its supremacy over other organic sources. The better performance of the crop under FYM could be attributed to the higher dry-matter production and harvest index even better than recommended fertilizers, which may be ascribed to its other beneficial effects including availability of micronutrients. Similarly, a significant enhancement in grain yield of rice over absolute control owing to the application of different organic sources of nutrients with significant increase in uptake of iron, zinc and manganese in the grains was earlier observed by Singh *et al.* (2011). Simi-

Table 2. Effect of organic nutrient management on growth and yield attributes of rice (mean of 2009–2013)

Treatment	Plant height (cm)	Productive tillers/hill	Total dry-matter (g/hill)	Panicles/m ²	Panicle length (cm)	Spikelets/panicle	Sterility (%)	Harvest index
<i>Rice variety</i>								
'Karjat 3'	76.5	10.5	26.7	283.8	22.1	137.3	18.15	0.42
'Revathy'	83.4	8.7	27.5	257.5	21.1	134.1	20.66	0.41
'Pusa Sugandh 5'	91.9	8.0	33.0	211.2	25.5	127.3	22.60	0.35
SEM±	1.03	0.16	0.92	3.21	0.14	2.24	0.90	0.02
CD (P=0.05)	4.16	0.64	3.72	12.95	0.57	9.04	–	0.04
<i>Nutrient sources</i>								
FYM	83.3	9.20	29.6	246.0	23.1	135.5	19.56	0.43
Vermi-compost	82.3	9.01	27.8	248.0	22.8	135.8	20.44	0.38
<i>Gliricidia</i> + <i>Eupatorium</i> sp.	84.5	9.51	29.6	263.5	23.1	132.9	20.35	0.42
Paddy straw + water hyacinth	86.2	8.98	29.5	250.8	23.3	135.8	21.03	0.39
<i>Sesbania rostrata</i>	83.7	9.02	29.5	254.50	22.4	136.9	20.02	0.36
Recommended NPK	88.7	9.47	29.6	262.2	23.4	140.8	21.60	0.38
Control	78.9	8.34	28.0	231.0	22.4	128.40	20.28	0.37
SEM±	0.60	0.16	1.08	4.14	0.30	1.65	0.62	0.02
CD (P=0.05)	1.73	0.45	–	11.12	–	4.74	–	–
<i>Interaction</i>								
SEM±	2.73	0.42	2.44	8.50	0.37	5.93	2.39	0.04
CD (P=0.05)	–	0.86	5.86	–	–	–	–	–

soils also observed better nutrient uptake by rice and soil-fertility status under FYM treatment.

Significantly higher available nitrogen levels were observed in soils with continuous application of FYM for 5 years as compared to recommended fertilizer application. The higher nitrogen content in FYM contributed for this increase. Among the other sources, vermi-compost recorded relatively higher available N in soil than the absolute control or the recommended fertilizers which may be attributed to the better manurial value of the material. Sujatha *et al.* (2014) also observed that among the different organic manurial treatments, application of 100% RDN through FYM recorded the highest amount of NPK in soil after harvesting of rice.

Although the pooled mean phosphorus content of the soil did not differ significantly, relatively higher soil phosphorus was observed with the application of FYM and it was followed by vermi-compost application, showing the supremacy of these organic manurial resources (Table 6). Continuous application of FYM over a period of 5 years accumulated 11.8% more phosphorus as compared to the application of even the recommended fertilizers. Blake *et al.* (2000) also observed that the application of P either as fertilizer or manure had a considerable influence on the availability, uptake, leaching or fixing of P, but the crop recovery rate of P from mineral fertilizer did not exceed 35% with the smallest recovery (average 18%) occurring in the soil with the highest clay content. Most efficient utilization of P (averages of 47% and 37% respectively)

was from soils treated with farmyard manure (FYM), with the greater quantity of P either leached or fixed (8 and 25 kg/ha/year respectively) occurring in soils treated with superphosphate.

It was observed that the potassium content in the soil were drastically reduced after 5 rice crops with the application of either organic manurial sources or the recommended fertilizers as compared to the initial level, indicating the higher requirement of the crop. However, relatively higher potassium content in soil in the fixed plots was recorded with continuous application of *Gliricidia* + *Eupatorium*, paddy straw along with water hyacinth and FYM. Higher potassium content of water hyacinth and *Gliricidia* loppings coupled with a sizeable slow decomposing organic matter added to the soil in these treatments might have favoured for higher residual soil potassium over 5 years. Earlier workers Rao *et al.* (2014) observed decrease in the status of available soil potassium in all the nutrient-management practices in rice regardless of source of nutrients while Pooniya and Shivay (2011) observed a significantly higher available nutrients in soil after harvest of basmati rice with *Sesbania aculeata* green manure application..

Influence on soil microbial population

Application of vermi-composting generally influenced relatively higher buildup of both bacterial and actinomyces growth in soil as compared to their earlier population (Table 7). It was followed by *Gliricidia* with *Eupa-*

Table 4. Straw yield and sustainability yield index of rice varieties with different organic nutrient management during 2009–2013

Treatment	Straw yield of rice (t/ha)					Pooled mean	Sustainability yield index (SYI)
	2009	2010	2011	2012	2013		
<i>Varieties</i>							
'Karjat 3'	5.10	6.98	7.36	5.54	7.54	6.45	0.80
'Revathy'	5.96	7.45	8.51	4.43	5.95	6.41	0.66
'Pusa Sugandh 5'	6.34	7.12	7.90	7.97	6.07	7.01	0.85
SEm±	0.12	0.51	0.97	0.34	0.14	0.36	0.04
CD (P=0.05)	0.50	–	–	1.37	0.56	–	–
<i>Nutrient sources</i>							
FYM	5.28	6.24	8.87	6.85	5.59	6.64	0.71
Vermi-compost	5.22	6.80	7.54	5.37	7.12	6.41	0.72
<i>Gliricidia</i> + <i>Eupatorium</i> sp.	6.48	7.22	8.25	5.90	6.21	6.88	0.79
Paddy straw + water hyacinth	5.89	7.79	7.51	6.66	6.79	6.62	0.76
<i>Sesbania rostrata</i>	5.11	7.20	7.71	5.56	6.46	6.50	0.81
Recommended NPK	7.46	7.81	9.72	7.39	7.62	7.99	0.80
Control	5.14	7.20	5.85	4.10	5.86	5.33	0.79
SEm±	0.21	0.31	0.43	0.17	0.34	0.13	0.03
CD (P=0.05)	0.60	0.90	1.24	0.48	0.99	0.39	0.07
<i>Interaction</i>							
SEm±	0.33	1.36	2.56	0.90	0.37	0.96	0.12
CD (P=0.05)	1.10	–	–	1.04	1.75	0.86	0.16

torium sp. application, showing their superiority to support the microbial growth. Higher fungal population was observed both in FYM and vermi-compost treated plots as compared to their earlier levels. The higher microbial growth under these treatments may be attributed to the sufficient quantities of organic matter through vermi-compost and FYM that might have served as a better substrate for the microbial growth and the favourable soil environment. The buildup of all the 3 microbial groups, viz. bacteria, actinomycetes and fungi, was relatively lower in fertilizer-applied plots, indicating the detrimental effect of fertilizer chemicals on the microbial growth. In similar studies earlier, Singh *et al.* (2007) and Kumari Niru *et al.* (2013) also observed enhanced soil microbial population owing to the application of organic amendments in comparison to absolute control as well as recommended fertilizer application. Further, Singh *et al.* (2011) also observed increased microbial population with organic sources of nutrients in rice with a notable enhancement in the dehy-

drogenase activity.

Economics of organic nutrient management

Among the rice varieties, growing medium duration rice variety 'Karjat 3' was found more economical as reflected both in terms of gross returns, net returns and the benefit: cost ratio (Table 8). The higher returns from 'Karjat 3' could be attributed to its higher grain and straw yields.

Among the nutrient sources, application of *Gliricidia* with *Eupatorium* sp. application accounted at par net returns with the recommended fertilizer application, recording 96.5% of the latter owing to its beneficial impact on yield coupled with lower cost of the resource. Further, the intrinsic benefits of organic production in terms of favourable soil chemical and biological environment will be an added advantage.

The net benefit: cost ratio was although higher for absolute control, it was on a par with recommended fertiliz-

Table 5. Soil fertility parameters as influenced by different organic nutrient management during 2009–2013

Nutrient sources	Organic Carbon (%)					Available N (kg/ha)				
	After first year	After second year	After third year	After fourth year	After fifth year	After first year	After second year	After third year	After fourth year	After fifth year
	FYM	0.93	1.44	1.56	1.31	1.24	192.3	197.2	189.8	228.9
Vermi-compost	1.25	1.21	1.30	0.77	1.04	192.3	185.4	182.9	195.4	235.0
<i>Gliricidia</i> + <i>Eupatorium</i> sp.	1.09	1.24	1.56	0.82	1.01	194.2	189.2	169.8	189.1	217.0
Paddy straw + water hyacinth	1.46	1.36	1.43	1.05	1.09	179.2	191.3	200.4	217.7	233.0
<i>Sesbania rostrata</i>	1.20	1.31	1.35	0.91	0.93	205.3	203.5	187.3	193.5	228.0
Recommended NPK	1.07	1.25	1.24	0.90	1.05	186.7	178.6	178.6	169.9	220.0
Control	1.14	1.23	1.25	0.91	1.14	184.8	192.0	178.0	189.2	230.0
SEm±	0.09	0.04	0.12	0.22	0.07	5.87	4.96	18.78	10.50	5.97
CD (P=0.05)	0.26	0.11	0.34	–	–	16.20	13.70	–	29.44	17.2

Soil had a initial content of organic carbon 0.58% and available N 154.9 kg/ha

Table 6. Soil fertility parameters as influenced by different organic nutrient management during 2009–2013

Nutrient sources	Available P ₂ O ₅ (kg/ha)					Available K ₂ O (kg/ha)				
	After first year	After second year	After third year	After fourth year	After fifth year	After first year	After second year	After third year	After fourth year	After fifth year
	FYM	23.3	35.5	29.5	27.7	16.0	127.3	154.4	222.4	98.7
Vermi-compost	21.2	34.1	30.2	27.8	14.5	112.0	122.2	186.4	108.0	75.7
<i>Gliricidia</i> + <i>Eupatorium</i> sp.	14.1	31.1	19.8	23.0	13.9	95.7	140.2	181.6	103.1	87.5
Paddy straw + water hyacinth	24.6	32.6	31.2	24.1	13.3	137.6	164.0	227.1	110.0	83.0
<i>Sesbania rostrata</i>	22.0	29.4	19.7	25.9	11.3	98.7	123.3	176.2	97.1	76.7
Recommended NPK	22.6	31.8	25.2	28.2	14.3	86.0	107.3	188.0	112.9	69.6
Control	17.2	32.7	28.5	28.3	13.0	107.6	136.7	179.8	97.3	63.8
SEm±	2.20	1.34	6.78	4.21	1.06	14.27	10.90	28.37	7.25	8.61
CD (P=0.05)	6.08	3.7	–	–	–	39.40	30.1	–	–	–

Soil had a initial content of available P₂O₅-21.1 kg/ha and available K₂O- 188 kg/ha.

Table 7. Influence of different organic nutrient management on microbial population during 2009–2013

Nutrient source	Microbial population								
	Bacteria (10^5 CFU/g)			Actinomycetes (10^4 CFU/g)			Fungi (10^3 CFU/g)		
	After 1 st year	After 3 rd year	After 5 th year	After 1 st year	After 3 rd year	After 5 th year	After 1 st year	After 3 rd year	After 5 th year
FYM	13.11	40.94	21.94	9.22	51.94	43.33	8.00	28.61	64.67
Vermicompost	13.83	45.83	24.72	9.67	47.17	53.39	6.94	30.11	56.17
<i>Gliricidia</i> + <i>Eupatorium</i> sp.	7.94	37.67	20.17	7.72	42.28	46.00	6.39	30.67	41.28
Paddy straw + water hyacinth	10.83	32.78	19.50	9.33	49.50	40.33	7.33	26.50	38.39
<i>Sesbania rostrata</i>	17.50	35.61	22.28	10.28	39.17	40.17	10.39	27.17	39.00
Recommended NPK	9.83	38.44	17.22	11.33	39.41	39.17	5.61	28.61	43.61
Control	13.66	40.83	20.22	8.45	56.78	45.22	7.33	37.22	43.33
SEm±	5.34	7.09	2.65	1.91	7.07	3.78	4.01	4.24	10.24
CD (P=0.05)	9.31	–	–	3.17	–	–	6.65	–	–

Table 8. Economics* of rice varieties with different organic nutrient management during 2009–2013

	Gross returns ($\times 10^3$ ₹/ha)	Cost of production ($\times 10^3$ ₹/ha)	Net Returns ($\times 10^3$ ₹/ha)	Net benefit: cost ratio
<i>Varieties</i>				
‘Karjat 3’	73.3	47.2	26.1	0.55
‘Revathy’	63.1	46.2	16.9	0.37
‘Pusa Sugandh 5’	66.4	47.6	18.8	0.39
SEm±	0.80	0.05	0.67	0.02
CD (P=0.05)	1.91	0.12	2.70	0.09
<i>Nutrient sources</i>				
FYM	80.1	49.9	30.30	0.61
Vermicompost	71.8	102.4	–	–
<i>Gliricidia</i> + <i>Eupatorium</i> sp.	76.6	36.6	40.0	1.09
Paddy straw + water hyacinth	73.5	52.2	21.3	0.41
<i>Sesbania rostrata</i>	72.1	35.4	36.6	1.04
Recommended NPK	72.1	30.6	41.7	1.35
Control	59.7	24.0	35.7	1.49
SEm±	2.1	6.3	1.7	0.05
CD (P=0.05)	4.9	15.0	5.1	0.14
<i>Interaction</i>				
SEm±	3.58	10.85	1.77	0.06
CD (P=0.05)	8.57	25.93	–	–

*Considering 20% higher price for the organic produce

ers. As the practice of no manure or only fertilizer application is not sustainable in the long run, there is only little practical feasibility for the same. However, there is much potential to adopt application of *Gliricidia* along with *Eupatorium* sp. for large scale in the region which also recorded equally better benefit: cost ratio owing to the easy availability of the resources to improve the soil fertility as well as its long-term implications in reducing the menace of the noxious weed *Eupatorium* sp. in the environment. Earlier, Surekha *et al.* (2013) also observed improvement in the benefit: cost ratio with the organics over the years.

Thus, it can be concluded that selection of rice ‘Karjat

3’ for organic production under west coast situations of India is both productive and profitable. Use of FYM or *Gliricidia* along with *Eupatorium* sp. as a nutrient source for organic rice cultivation is not only more productive and profitable, but also sustains the soil fertility.

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