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Agronomic assessment of different rice hybrids for sustainable production through agronomic manipulation under high rainfall conditions of Konkan

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Abstract
Two years research experiment was conducted during *Kharif* season of 2015 and 2016 to investigate the, "Agronomic assessment of different rice hybrids for sustainable production through agronomic manipulation under high rainfall conditions of Konkan" at Agronomy Farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.). The field experiment was laid out in split-split plot design comprising 48 treatment combinations replicated thrice. Main plot treatment consisted of four sowing times *viz*., 23rd metrological week (4th to 10th June) (S_1), 25th metrological week (18th to 24th June) (S_2), 27th metrological week (2nd to 8th July) (S_3) and 29th metrological week (16th to 22th July) (S_4). The sub plot treatment consisted of four rice hybrids *i.e.* Sahyadri (H_1), Sahyadri 3 (H_2), Suruchi 5401 (H_3) and PA 6444 (H_4) while, sub-sub plot treatment comprised of three age of seedling, *viz*., 15 days after sowing (A_1), 30 days after sowing (A_2) and 45 days after sowing (A_3).
The growth characters of rice *viz*., mean plant height, number of functional leaves hill^{-1}, number of tillers hill^{-1}, dry matter accumulation hill^{-1} yield attributes and yields were significantly enhanced due to sowing during 23rd meteorological week over 25th, 27th and 29th meteorological week in that descending order of significance. Significantly more growth, yield attributes and yield of rice was recorded in the hybrid Sahyadri 3 (H_2) which were at par with hybrid PA 6444 (H_4) and recorded significantly superior growth parameter over rest of hybrids at all stages of crop growth during both the years of investigation and transplanted with 15 days old seedling recorded more growth and yield during both years of study.

Keywords: Rice, sowing time, hybrids, age of seedling, growth and yield

Introduction
Rice (*Oryza sativa* L.) is the most important staple food grain crop of the world which constitutes the principle food for about 60 per cent of the world's population. In India, rice cultivation contributes to the total food grain production by 43 per cent and to the total cereal grains production by 46 per cent. The Asia Pacific region produces and consumes more than 90 per cent of the world's rice. Rice based production system provides the income and employment for more than 50 million households. Therefore, rice is not only a staple food of the region but also a way of life.
There is an urgent need to adopt some innovative technologies to break the yield ceiling in rice. Among the available technological options to enhance rice production and productivity, hybrid rice is the most practically feasible and readily adoptable technology. Potential of this technology in boosting rice production has been well demonstrated in the peoples, Republic of China during last three decades. In 1976 first rice hybrid was released for general cultivation in China. In China hybrid rice cultivated about 55 per cent of rice growing area with 66 per cent of the total rice grain production.
Rice is cultivated on about 163.1 million hectares area with total production of 722.56 million tonnes with average productivity of 4.4 tonnes ha^{-1} at world level (Anonymous 2016) [3]. India is the world's second largest rice producer and consumer next to China. Total area under rice in India was 44.11 million hectares with annual production of 108.50 million tonnes during 2015 (Anonymous, 2015) [1]. In Maharashtra, area under rice is 15.51 lakh ha with 29.46 lakh tonnes production. Average productivity of rice is 2.13 tones ha^{-1} in India and 1.68 tones ha^{-1} in Maharashtra, which are far below the world's average of 4.4 tonnes ha^{-1}.

The major rice growing districts in Maharashtra are Thane, Raigad, Ratnagiri, and Sindhudurg along with the west coast and Bhandara and Chandrapur in the eastern parts of the states. Rice is also grown in minor areas of Tuljapur, Parbhani, Western Ghat of Pune, Satara, and Kolhapur (Anonymous, 2016) [3].

In Konkan, rice is cultivated over an area of 4.20 lakh hectares with an annual production of about 10.73 lakh tones with average productivity of 2.40 tones ha^{-1} (Anonymous, 2016) [3]. Rice based agriculture is the largest source of livelihood of majority of rural mass in Konkan, about 80 per cent of rice crop is a low land, spreading over a 40-60 km in width and stretching to a length of 700 km all along the west-coast. But the yields are highly variable due to aberration in weather like late onset of monsoon, heavy continuous rains, intermittent dry spell and heavy rains at the time of harvesting, etc. continuous adoption of puddling and transplanting for rice cultivation has been reported decline soil and crop productivity (Nambiar and Abrol, 1989) [9].

The present production level of rice needs to be increased in order to meet the ever-growing population pressure on the land to reach self-sufficiency in food grain production in the country. Since there is little scope for expanding the rice area, it is necessary to increase the rice productivity from unit land area. Therefore, hybrid rice is practically feasible and readily adaptable genetic option to increase the rice productivity. The rice hybrids perform well under well managed conditions and have higher yield potential. Hybrid rice cultivation is recommended in situations where yield levels have reached a plateau and further increase in yield are not possible through conventional varieties. The higher yield of hybrids can be realized with proper management practices. Vishwakarma (2015) [15] reported that hybrid rice could yield 20-30 per cent more than conventional varieties with proper management. So, adequate agronomic management is essential to achieve potential yield in hybrid rice.

Time of sowing is the most important factor in influencing the yield of the crop. Performance of a genotype entirely depends upon the time of planting. Delay in planting generally results in yield reduction which cannot be compensated by any other means. Hybrids have relatively higher degree of thermo sensitivity during flowering and grain filling stages as compared to high yielding varieties. Too high or too low temperature may cause damage on flowering and prevent pollen shedding leading to increased infertility and production of chaffy grains. In order to ensure normal flowering, fertilization and avoid damage due to high or low temperature, it is necessary to properly organize the date of nursery sowing and transplanting of hybrids rice.

Sowing of rice during the optimum time resulted in high grain yield. However, optimum rice planting dates are region specific and vary with the location and varieties. Delay in sowing results in reduction of plant height, productive tillers, filled grains $panicle^{-1}$ and grain yield (Shah and Bhurer, 2005) [13]. Therefore, it is necessary to know the optimum sowing time, which is a critical aspect for rice cultivation in Konkan as intensive and continuous rain occurs after regular onset of monsoon.

Generally, farmers raise rice nursery about a month earlier for normal planting, expecting timely availability of water. Of late, due to delay in the onset of monsoons and frequent drought, filling of reservoirs and tanks is delayed. This situation forces the farmers to wait for the water which leads to delayed transplanting of over aged seedlings. Labour scarcity during the peak season of transplanting is another reason for late planting with over aged seedlings. Farmers generally grow short, medium to long duration varieties during kharif in Maharashtra region. All the varieties will not perform equally, when transplanted with over aged seedlings. Under these circumstances, suitable variety is required for getting higher yields (Naresh, 2012) [10].

Age of seedling is an important factor to obtain higher yield of rice because it has tremendous influence on the tiller production, grain formation and other yield attributes. The use of over aged seedlings retards the general performance of crop and reduces the yield of crop (Bozorgi *et al*., 2011) [4]. Timely transplanting of rice results in earlier harvest and allows timely planting of the next crops. Timely transplanting of rice crop is also found to increase the rain water use efficiency as compared to the delayed planting. Therefore, it is essential to evaluate different hybrids rice for sustainable production under changing climatic condition through agronomic manipulation.

Materials and methods

The field experiment was conducted during *Kharif* season of 2015 and 2016 at Department of Agronomy Farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.). The soil of the experimental plot was clay loam in texture, moderately acidic in reaction, high in organic carbon content. It was medium in available nitrogen, low in available phosphorus and fairly high in available potassium during the both years of experimentation.

The field experiment was laid out in split-split plot design comprising 48 treatment combinations replicated thrice. Plot size (Gross: 4.00 m X 3.00 m and Net : 3.60m X 2.70 m) Main plot treatment consisted of four sowing times *viz*., 23rd metrological week (4th to 10th June) (S_1), 25th metrological week (18th to 24th June) (S_2), 27th metrological week (2nd to 8th July) (S_3) and 29th metrological week (16th to 22th July) (S_4). The sub plot treatment consisted of four rice hybrids *i.e.* Sahyadri (H_1), Sahyadri 3 (H_2), Suruchi 5401 (H_3) and PA 6444 (H_4) while, sub-sub plot treatment comprised of three age of seedling, *viz*., 15 days after sowing (A_1), 30 days after sowing (A_2) and 45 days after sowing (A_3).

During the course of present investigation, periodical growth, yield contributing characters and yield were recorded to evaluate the treatment effects.

Result and discussion

Effect of sowing time

Height of the plant, number of functional leaves $hill^{-1}$, number of tillers $hill^{-1}$ and dry matter accumulation $hill^{-1}$ (g) was increased with the advancement in age of crop and numerically maximum growth character was observed in sowing 23rd meteorological week (4th to 10th June) (S_1) (Table 1) during both the years of investigation. The sown in 25th meteorological week (18th to 24th June) (S_2) recorded higher plant height, number of functional leaves $hill^{-1}$, number of tillers $hill^{-1}$ and dry matter accumulation $hill^{-1}$ (g) of rice hybrids followed by 27th meteorological week (2nd to 8th July) (S_3) and 29th meteorological week (16th to 22th June) (S_4) in that descending order of significances during both years of study which might be due to more favorable weather condition associated and was criticized by the higher growing degree days and hydrothermal units gained in the 23rd meteorological week sowing. The other reason of high dry matter accumulation in 23rd meteorological week may be due to the significant increase in morphological parameters which responsible for the photosynthetic capacity of the plant

thereby increasing the straw yield. The result conformed with Bozorgi *et al* (2011) [4]. The beneficial effect of sowing during 23rd meteorological week in enhancing the growth through increased crop height, leaves, number of tillers, leaf area index and dry matter production ultimately reflected in higher yield contributing characters *viz*., number of panicle hill^{-1}, length of panicle, test weight, weight of filled grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1}. The grain yield of rice was a function of all these yield attributes of an individual plant and ultimately grain yield obtained from the plant.

The sowing during 23rd meteorological week was significantly superior in terms of some yield contributing characters *viz*., number of panicle hill^{-1}, length of panicle^{-1} (cm), number of filled grains panicle^{-1}, weight filled grain panicle^{-1} and 1000 grain weight and it was decreased significantly in the 25th, 27th and 29th meteorological week in that descending order during both the years of experimentation. These results are in close confirmation with Shah and Bhurer (2005) [13] and Navalgi *et al*. (2011) [11]. The higher percent unfilled grain in 29th meteorological week (S_4) was probably due to severe less favorable environment and delay sowing subsequently more incidents of insect, pest and shortage of water at time of grain filling stage. The present results are in consonance with finding of Navalgi *et al*. (2011) [11].

Significantly the highest grain yield of 87.79 and 76.21 q ha^{-1} during the years 2015 and 2016 respectively, was recorded by sowing with 23rd meteorological week (S_1) followed by sowing 25th, 27th and 29th meteorological weeks in that descending order of significance. Similar trend was also observed in straw yield (Table 1) during both the years of experimentation. The increased yield might be due to result of optimum growth and development parameters associated with 23rd meteorological week sowing, favourable weather condition responsible for more growth and development of crop. The results are in the conformity with the work done by Murty *et al*. (2007). The increased yield attributes might be due to increased growth and development parameters which ultimately resulted in increased grain. These results corroborated the findings of Vishwakarma (2015) [15] and Singh and Singh (2016) [14].

Table 1: Effect of sowing times and age of seedling on growth character of different rice hybrids during *kharif* 2015 and 2016

Treatment	Plant height (cm)		Number of functional leaves hill^{-1}		Number of tillers hill^{-1}		Dry matter accumulation hill^{-1} (g)	
	2015	2016	2015	2016	2015	2016	2015	2016
A. Sowing times (S):								
S_1 : 23rd MW	102.06	86.23	10.17	9.99	18.50	18.10	48.10	44.52
S_2 : 25th MW	98.18	83.22	9.79	9.59	17.83	17.33	45.65	41.61
S_3 : 27th MW	94.55	80.92	9.47	9.26	17.15	16.47	33.29	31.89
S_4 : 29th MW	87.01	77.03	9.15	8.92	14.08	13.78	18.33	19.11
S.Em. ±	0.84	0.48	0.09	0.09	0.19	0.19	0.38	0.24
C.D. at 5%	2.92	1.66	0.31	0.32	0.66	0.65	1.30	0.83
B. Hybrids (H):								
H_1 : Sahyadri	94.99	81.36	9.71	9.39	16.76	16.26	36.18	34.12
H_2 : Sahyadri - 3	97.76	84.52	9.88	9.71	17.43	16.99	37.94	35.48
H_3 : Suruchi - 5401	92.22	78.63	9.32	9.21	16.31	15.82	34.22	32.98
H_4 : PA - 6444	96.84	82.91	9.68	9.45	17.06	16.61	37.03	34.56
S.Em. ±	0.91	0.57	0.15	0.12	0.14	0.15	0.58	0.36
C.D. at 5%	2.65	1.67	NS	NS	0.42	0.43	1.69	1.06
C. Age of seedlings (A):								
A_1 : 15 DAS	100.25	87.39	7.10	6.57	20.57	19.89	38.94	36.67
A_2 : 30 DAS	95.72	80.94	10.96	10.99	13.80	13.53	36.23	33.89
A_3 : 45 DAS	90.38	77.23	10.88	10.76	16.30	15.84	33.86	32.30
S.Em. ±	0.75	0.67	0.10	0.10	0.19	0.12	0.39	0.30
C.D. at 5%	2.12	1.91	0.29	0.27	0.53	0.35	1.10	0.83
Interaction effect								
S x H	Sig	Sig	NS	NS	NS	NS	NS	NS
S x A	NS	Sig	NS	NS	NS	NS	NS	NS
H x A	NS	NS	NS	NS	NS	NS	NS	NS
S x H x A	NS	NS	NS	NS	NS	NS	NS	NS
General mean	95.45	81.85	9.65	9.44	16.89	16.42	36.34	34.29

Effect of hybrids

During this stage, growth and development parameters of rice *viz*., plant height, functional leaves hill^{-1}, number of tillers and dry matter accumulation (g) hill^{-1} showed significant differences due to different hybrids in rice during both years of experimentation. The rice hybrids Sahyadri 3 (H_2) recorded significantly more plant height, functional leaves, number of tillers and dry matter accumulation of rice over rest of hybrids during both the years. Which were closely followed by hybrid PA 6444 (H_4) and found at par with each other during both years. The higher tiller production was due to better inducement of root growth for anchorage. It leads to better nutrient and water uptake and ultimately leads to higher number of tillers, dry matter accumulation. Further, hybrid PA 6444 (H_4) which found similar with hybrid Sahyadri (H_1) and at par with each other to all the growth characters during both years. The rice hybrid Suruchi 5401 (H_3) recorded significantly lowest plant height, functional leaves, number of tillers, dry matter accumulation and leaf area of rice over rest hybrids during both the years study. The results are in confirmation with the results reported by Jain and Upadhyay (2008) [7] and Vishwakarma (2015) [15].

Perusal of the data presented in table 2 and 3 revealed that hybrid Sahyadri-3 produced significantly the highest length of panicle, weight of filled grains panicle^{-1}, number of filled grains panicle^{-1} and least value of number unfilled grains panicle^{-1} during both the years and followed by hybrid PA 6444 which were on par with each other and significantly

superior over rest of hybrids rice though the quantum was more pronounced in all the yield characters (Tables 14). The hybrid PA 6444 was at par with Sahyadri in the entire yield contributing characters *viz*., number of panicle hill^{-1}, length of panicle-^{1}, weight of filled grains panicle^{-1} and number of filled grains panicle^{-1}. The hybrid Sahyadri-3 produced significantly higher test weight than rest of the hybrids and was followed by another hybrid Sahyadri during both years. The similar results were also reported by Vishwakarma (2015) [15] and Singh and Singh (2016) [14].

The hybrid Sahyadri 3 (H_2) recorded significantly more grain yield of 66.24 and 56.24 q ha^{-1} during both the years respectively, which was followed by hybrid PA 6444 (H_4) and gave 63.70 and 54.96 q ha^{-1} grain yields during the years 2015 and 2016 respectively. Similar trend was also observed with straw yield (Table 3) during both the years of experimentation. This is might be due to nature of hybrid and their inherent capability to produce higher growth and resulted in production of more number of yield attributes. It indicated that genetic make-up of different hybrids produced variation of yield attributes in different hybrids in the present study. Genetic traits of hybrid Sahyadri 3 allowed the rice plant to transform more energy into the better production of yield attributes and proved advantageous in increasing the yield potential by about 4.31, 6.28 and 12.06 per cent, respectively. The results are in confirmation with the results reported by Jain and Upadhyay (2008) [7].

Table 2: Effect of sowing times and age of seedling on yield attributes of different rice hybrids during *kharif* 2015 and 2016

Treatment	Number of Panicle hill^{-1}		Length of panicle^{-1} (cm)		Filled grain Panicle^{-1}		Unfilled grain Panicle^{-1}	
	2015	2016	2015	2015	2016	2015	2015	2016
A. Sowing times (S):								
S_1 : 23rd MW	12.27	11.96	26.68	26.26	103.88	101.52	11.14	13.78
S_2 : 25th MW	11.61	11.10	26.11	25.34	93.86	90.66	17.12	18.85
S_3 : 27th MW	10.58	10.20	25.64	24.48	81.51	78.86	25.64	27.79
S_4 : 29th MW	8.41	7.99	24.51	24.12	63.25	60.00	40.56	42.50
S.Em. ±	0.16	0.23	0.13	0.09	1.80	0.94	0.49	0.30
C.D. at 5%	0.54	0.78	0.46	0.31	6.23	3.25	1.69	1.05
B. Hybrids (H):								
H_1 : Sahyadri	10.70	10.23	25.71	25.19	85.04	83.52	23.61	25.98
H_2 : Sahyadri – 3	11.21	10.81	26.51	25.54	91.71	88.23	21.50	23.93
H_3 : Suruchi – 5401	9.98	9.72	24.46	24.26	77.33	73.57	26.22	27.36
H_4 : PA – 6444	10.98	10.50	26.27	25.21	88.42	85.72	23.12	25.64
S.Em. ±	0.14	0.13	0.22	0.12	1.62	1.17	0.35	0.32
C.D. at 5%	0.42	0.38	0.65	0.36	4.74	3.41	1.02	0.92
C. Age of seedlings (A):								
A_1 :15 DAS	11.56	11.07	26.45	25.97	93.56	88.69	21.78	24.49
A_2 :30 DAS	10.57	10.28	25.79	24.96	85.01	82.33	23.53	25.35
A_3 :45 DAS	10.03	9.60	24.97	24.22	78.31	77.25	25.53	27.34
S.Em. ±	0.13	0.12	0.13	0.11	1.23	0.90	0.33	0.27
C.D. at 5%	0.35	0.33	0.37	0.31	3.48	2.55	0.93	0.77
Interaction effect								
S x H	NS	NS	NS	NS	NS	NS	NS	NS
S x A	NS	NS	NS	NS	NS	NS	NS	NS
H x A	NS	NS	NS	NS	NS	NS	NS	NS
S x H x A	NS	NS	NS	NS	NS	NS	NS	NS
General mean	10.72	10.31	25.74	25.05	85.62	82.76	23.61	25.73

Table 3: Effect of sowing times and age of seedling on yield attributes and yield of different rice hybrids during *kharif* 2015 and 2016

Treatment	Wt. of grain panicle^{-1} (g)		Test weight (g)		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	2015	2016	2015	2015	2016	2015	2015	2016
A. Sowing times (S):								
S_1 : 23rd MW	2.53	2.25	26.45	26.22	87.79	76.21	102.28	92.88
S_2 : 25th MW	2.34	2.15	26.10	25.79	81.69	66.38	93.98	84.08
S_3 : 27th MW	1.99	2.01	25.72	25.07	54.35	50.51	68.55	59.85
S_4 : 29th MW	1.67	1.49	25.06	24.46	26.39	20.47	37.79	33.54
S.Em. ±	0.03	0.02	0.10	0.10	0.92	0.98	1.09	0.76
C.D. at 5%	0.09	0.07	0.35	0.35	3.19	3.38	3.78	2.63
B. Hybrids (H):								
H_1 : Sahyadri	2.17	1.98	26.11	25.67	61.92	53.01	75.49	66.93
H_2 : Sahyadri – 3	2.20	2.05	26.42	26.01	66.24	56.24	79.28	71.41
H_3 : Suruchi – 5401	1.98	1.88	24.98	24.57	58.36	49.35	70.21	63.02
H_4 : PA – 6444	2.19	1.99	25.81	25.28	63.70	54.96	77.61	68.99
S.Em. ±	0.02	0.03	0.11	0.14	1.01	0.88	1.20	0.97
C.D. at 5%	0.06	0.08	0.32	0.41	2.96	2.58	3.50	2.82
C. Age of seedlings (A):								
A_1 :15 DAS	2.21	2.05	26.15	25.70	68.70	59.57	79.91	70.95
A_2 :30 DAS	2.12	1.97	25.79	25.34	62.04	52.43	76.22	66.46
A_3 :45 DAS	2.06	1.90	25.56	25.11	56.93	48.18	70.81	65.35

S.Em. ±	0.01	0.02	0.10	0.09	1.27	0.73	1.02	0.84
C.D. at 5%	0.04	0.06	0.29	0.25	3.59	2.06	2.88	2.38
Interaction effect								
S x H	NS	NS	NS	NS	NS	NS	NS	NS
S x A	NS	NS	NS	NS	NS	NS	NS	NS
H x A	NS	NS	NS	NS	NS	NS	NS	NS
S x H x A	NS	NS	NS	NS	NS	NS	NS	NS
General mean	2.13	1.98	25.83	25.38	62.55	53.39	75.65	67.59

Effects of age of seedling

Transplanting of 15-day old seedling significantly produced more plant height, number of functional leaves hill^{-1}, number of tillers hill^{-1}, leaf area, leaf-area index and dry matter accumulation taller plants as compared to 30- and 45-day old seedling during both the years. This was might be due to transplanting of seedlings from younger stage provides sufficient nutrients for vegetative growth by effective utilization of phyllochronic concept and saved energy diverting during nursery for tillering as well as for reproductive phase which ultimately leads to increased plant height, number of functional leaves hill^{-1}, number of tillers hill^{-1}, leaf area, leaf-area index and dry matter accumulation Pramanik and Bera (2013) [12].

15 days old seedling significantly produced more number of panicles^{-1}, panicle length (cm), filled grains panicle^{-1}, weight panicle^{-1} (g) and test weight (g), grain yields and straw yield with lower number of unfilled grain panicle^{-1} (21.78 and 24.49) over 45 days old seedling during the first and second year, respectively. Similar findings were reported by Raj *et al.* (2008) and Ali *et al*. (2013). The increase in yield attributes may be accounted due to principles and concept of phyllochronic utilization that follow by younger age seedling and thus improved the growth parameters *viz.*, production of functional leaves hill^{-1} and higher leaf-area index that are the major source of photosynthetic activity in rice with proper partitioning of assimilates into the leaf, stems and roots.

It was also observed that age of seedling (15-day old) utilized early phyllochronic concept to produced significantly higher grain and straw yield (68.70 and 59.57 q ha^{-1}) over 30-day (62.04 and 52.43 q ha^{-1}) and 45-day (56.93 and 48.18 q ha^{-1}) old seedling in 2015 and 2016 respectively. The increment in yield under 15 days old seedling (A_1) was mainly be due to higher photosynthetic and metabolic efficiency for assimilation of energy and their partitioning in to the yield attributing characters *viz.*, number of panicle hill^{-1}, panicle length (cm), weight of filled grain panicles^{-1} (g), test weight (g) and filled grains panicle^{-1} with lower unfilled grains panicles^{-1} and thus increased the grain and straw yield and *vice versa* under both older aged seedling. These findings are confirmed by Pramanik and Bera (2013) [12] and Chaudhari *et al*. (2015) [5].

Interaction effects between the sowing times, hybrids and age of seedling

The interaction effects among sowing time, hybrid and age of seedling with respect to plant height were found to be significant during individual years of study. Plant height treatment combination of sowing time with hybrid (S_1H_2) recorded significantly the more plant height followed by treatment combinations S_1H_4, S_1H_1 and S_2H_2 which was at par with each other and significantly superior over rest of the treatment combinations during in 2015. In 2016 the treatment combination S_1H_2 recorded significantly higher plant height which was significantly superior over rest of treatment combination. Similar result was conforming to Gangwar and Sharma (1997)

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