Response of Transplanted rice to different Nitrogen and Phosphorus Fertilizer Rates in Fogera Plain, Northwest Ethiopia

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Abstract

An experiment was conducted at Fogera Plain during the rainy seasons of 2018/19 and 2019/20 to determine, economically optimum rates of Nitrogen and Phosphorus fertilizer on yield of transplanted rice. Five levels of N rates (0, 92, 184,276 & 368 kgha^{-1}) and four levels of P_2O_5 rates (0, 23, 46 & 92 kgha^{-1}) were combined factorially and laid in RCB Design with three replications. The combined analysis of variances showed a significant effect (P<0.001) on plant height, number of total tillers per m^2 and number of fertile panicles per m^2, grain yield, straw yield harvest index and panicle length. The highest grain yield (4.56 t ha-^{1}) was obtained at 368-46 N- P2O5 kg ha-^{1}. The economic analysis exhibited that combined application of 184-46 N- P2O5 kg ha-^{1} is the most profitable treatment with mean net benefit of 63928.2 Birr ha-^{1}. Therefore, it can be concluded that application of nitrogen and phosphorous fertilizers at rates of 184-46 N- P2O5 kg ha-^{1} is the best recommended for rainfed lowland transplanted rice production in Fogera plain

Keywords: Grain yield, N, P, Net benefit, rain fed transplanted low land rice

Introduction

Rice (*Oryza sativa* L.) is one of the most popular field crops in the world, being cultivated in different agro-ecosystems. Rice serves as the staple food for world's half population (Mohidem *et al*., 2022). Rice is a source of energy for major portion of world's population and ranks second after maize with respect to production (Manjappa and Shailaja 2014). The importance of the crop in terms of area of coverage volume of production and consumption has increased since the last decades. The total area under rice production has increased from about 29,866 ha in 2011 to over 57,576 ha in 2020. Te production during the same period has increased from 90,412 tons to more than 170,630 tons (CSA [Central Statistical Agency], 2020). Rice productivity also reached close to 3 t/ha in 2020 from 1.8 t/ha in 2005. The proliferation of improved rice production technologies over the last three-to-four decades is believed to have contributed to productivity growth.

Rice is generally established through direct seeding or by transplanting

(Pandey and Velasco, 2002). Direct seeding is the practice of sowing seeds directly in the main field (Farooqa *et al*., 2011). On the other hand, transplanting is the practice of raising seedlings in a nursery and moving them into the main field. The major advantages of transplanting over direct seeding are better weed suppression and higher grain yield (Farooqa *et al*., 2011). Ginigaddara and Ranamukhaarachchi (2011) reported that transplanted rice matured earlier and escaped terminal moisture stresses than direct seeded rice. Farmers in Fogera plains of northwestern Ethiopia generally establish rainfed lowland rice through broadcast direct seeding. Rice production in the study often faces the problem of terminal moisture stress owing to abrupt ending of rainfall at the reproductive and grain filling stages of the crop (Tilahun *et al*., 2012). The farmers spend much of their family labour and money on weeding.

There are a number factors contributed to low rice productivity in Ethiopia. Biotic and abiotic stresses causing extensive losses to sustainable rice production, imbalanced nutrient, leads to decreased grain yields, with marginal net returns (Zafar *et al.* 2018: 65-9; Wattoo *et al.* 2018).

Lack of appropriate agronomic management recommendations associated to soil fertility is among the major factors limiting rice production in Ethiopia. Nitrogen, phosphorus, and potassium are applied as fertilizers in large quantities to rice fields, and a deficiency of either of the nutrient. According to Molla and Sofonyas 2018, Nitrogen and phosphorus deficiency are the most limiting nutrients in agricultural soils of Ethiopia. Availability of plant nutrients, particularly nitrogen at various plant growth stages is of crucial importance in rice production (ShaRada *et al*., 2018; Daquiado, 2019). Determination and application of optimum nitrogen and phosphorous would have significant in improving rice productivity in the study area than blanket recommendation in the study area. This research was therefore conducted to determine economically optimum Nitrogen and Phosphorus fertilizer rate for transplanted rice production in Fogera plains.

Material and Methods

Description of the study area

A field experiment was conducted on transplanted rice in Fogera plain, South Gondar Zone of Amhara Regional State in 2018/19 and 2019/20 main cropping seasons. The experimental site is located between Latitude 11°49'55" North and Longitude 37° 37' 40" East at an altitude of 1815 meters above sea level. The study site receives average mean annual rainfall, minimum and maximum temperature of 1219 mm, 12.75°C and 27.37°C, respectively. The physic-chemical properties of the soils for the experimental is given in (Table 1). Total nitrogen content (%)

was 0.15, which is within the range of low levels (0.02- 0.5%) for tropical soils. The organic matter content of the soil was 2.76%, which is within a range of medium (2-4%) for Ethiopian soils as per criteria developed by Murphy (1968). The available P content of the experimental sites soil was 6.5 ppm, which lies in a range of deficiency (< 20-40mg/kg) for most crops (Landon, 1991). The CEC of the soil was 55.4 cmol kg^{-1} soils.

Table 1. Soil physicochemical properties of the experimental rice field before planting in Fogera Plain of Ethiopia

Sand (%)	Silt (%)	Clay (%)	Textural class	P^H (1:2.5)	EC (ds/m)	CEC (cmolekg^1)	Organic matter (%)	Organic carbon (%)	Total nitrogen (%)	Available phosphorus (ppm)
22	14	64	Clay	6.07	0.450	55.4	2.76	1.6	0.15	6.5

EC=Electron conductivity; CEC= Cation exchange capacity; ppm=parts per million; cmolekg^{-1}; =cent mol per kilogram; ds/m=Deci siemens per meter

Experimental Design and Treatment formation

A factorial combination of five levels of N rates (0, 92, 184,276 & 368 $kgha^{-1}$) and four levels of P_2O_5 rates (0, 23, 46 & 92 $kgha^{-1}$) to form treatment combination. The treatments arranged in randomized complete block design (RCBD) with three replications. The plot size of 12 m^2 (4 m x 3 m) with 1 m spacing between plots and blocks were used to conduct the field study. For field planting, seedlings were transplanted at the spacing of 25 cm between rows and 20 cm between plants. Three seedlings were planted per hill according to the planned treatment (Tilahun *et al.*, 2013). Urea fertilizer was applied for all the plots few days after transplanting just after the seedlings recover from the transplanting shook. The experimental plots were bunded manually to control mixing of treatments and the variety X-Jigna was used for this experiment.

Data Collection

Data were collected on plant height, panicle length, number of total tillers/m^2, and number of fertile panicle/m^2, number of filled grain/panicle, thousand seeds weight, grain yield, straw yield and harvest index.

Plant height was measured at maturity from five randomly selected plants in the net plot starting from the ground level to the tip of the Panicle using a measuring tape in centimeter and took the average plant height.

Number of total tillers were counted from the net plot by using quadrant (1m * 1m) from each plot at physiological maturity. It included both effective and non-effective tillers.

Panicle length was measured at maturity by calculating the average panicle length of five randomly selected plant samples from the net plots, following the measurement from its base to the tip of the panicle

Numbers of filled grain per panicle were counted from five randomly selected plant panicles in the net plot of each treatment and took the average of filled spikelets or grains

Biomass or biological yield was measured by weighing the sun dried total above ground plant biomass of the net plot

Grain yield was measured by taking the weight of the grains threshed from the net plot area and converted in tons per hectare after adjusting the grain moisture content to 14 % standard moisture content.

Straw yield was obtained as the difference of the total above ground plant biomass (straw + grain) and grain yield.

Thousand grain weights (g) were measured by weighing 1000 seeds in sensitive balance from each plot

Harvest index (HI %) of each treatment was calculated .by dividing the grain yield to the total above ground sun dried biomass multiplied by hundred.

Data analysis

All collected data were subjected to analysis of variance (ANOVA) using SAS software version 9.2 (SAS Institute, 2008). Since the test of homogeneity of variances for each parameter was non-significant, combined analysis of variance was done over the years to determine the main and interactions. Mean separation for treatments were calculated based on the ANOVA. The prevailing cost of inputs and out puts in year 2020 considered for the analysis. The cost of Urea and NPS fertilizers for the stated period at Fogera were Birr 13.1 and 14.3, respectively while the price of rice grain and straw were Birr 13.5 and 1.2, respectively.

Results and Discussion

Plant Height

The analysis of variance indicated that plant height of transplanted rice was very significantly ($P<0.001$) affected by the main effects of nitrogen rates, but not by phosphorous rates and their interaction (Table 2). The highest plant height (108.3 cm) was recorded from 368 kg ha^{-1}N, while the lowest plant height (85.7 cm) was recorded from the control, without N application (Table 2). The result indicated that plant height increased significantly by increasing the amount of fertilizer. In line with the present findings, Sah *et al.* (2019) had reported that different level of N caused significant difference in plant height, the height of plant found to increase from 60 kg^{-1} N to 120 kg Nha^{-1}.The increase in plant height of rice in response to the increase of N fertilizer rates was probably due to enhanced availability of N, which enhanced further cell division and more leaf area that in turn resulted in higher photo assimilates and thereby resulted in more dry matter accumulation (Shiferaw *et al.*, 2012).

Panicle Length

The analysis of variance indicated that panicle length of transplanted rice was highly significantly ($P<0.01$) affected by the main effects of nitrogen rates, but not by phosphorous rates and their interaction (Table 2). The highest panicle length (22.5 cm) exhibited at the rate of 368 kg ha^{-1} N, followed by 276 and 184 kg ha-^{1} N which was statistically similar (Table 2) whereas, the lowest panicle length (20.0 cm) was observed at the control without N fertilizer application. This result might be due to nitrogen takes part in panicle formation as well as panicle elongation and for this reason, panicle length increased with the increase of N fertilization. The findings of many authors had confirmed for the significant effect of nitrogen levels on panicle length (Fageria and Baligar, 2001; Gewaily *et al.*, 2018; Sah *et al.*, 2019). Sah *et al.*, (2019) recorded highest panicle length with 180 kg N application while Fageria and Baligar, (2001) stated nitrogen application of 210 kg ha^{-1} exhibited larger panicle length. Riste *et al.* (2017) stated that highest and significant panicle length (27.06 cm) was recorded with application of fertilizer dose at 60 kg Nha^{-1}compared to the control without N fertilizer. On the other hand, Molla and Sofonyas (2018) reported longest panicles of 20.19 cm at the rate of 46 kg N ha^{-1}, while they noted shortest panicles in the control plots.

Number of Tillers and Fertile panicles Per m²

The analysis of variance showed that number of tillers and number of fertile panicles/m^2 were very highly significantly ($P<0.001$) affected by the main effects of nitrogen but not by phosphorous. Whereas, the interaction of N and P were very highly significantly ($P<0.001$) affecting the number of tillers and fertile panicles/m^2 (Table 2). The highest number of tillers and fertile panicles (363 and 332) was recorded at the highest rate of 368 kg ha^{-1} N while their lowest number (268 and 152) was observed at the control (without N fertilizer) application respectively (Table 2). Similarly, the highest number of tillers and fertile panicles were exhibited at the rate of 46 kg ha^{-1} P2O5, which were statistically at par at the rate of 23 kg ha^{-1} P2O5 (Table 2). Number of tillers and fertile panicles per m^2 very highly significantly ($P<0.001$) affected the interaction of nitrogen and phosphorous fertilizer applications. The highest number of total tillers was observed at the interaction of 368 kg ha^{-1} N and 46 kg ha^{-1} P2O5, while the lowest number of total tillers was recorded at the control treatments (Table 2). This result might be due to application of sufficient amount of nitrogen and phosphorus fertilizer enhanced for the formation of different organs in the rice plant and facilitates other physiological processes. In line with the present results, among the yield attributes, the number of productive tillers is an important agronomic trait, which finally determines the number of fertile panicles and grain yield per unit land area (Ginigaddara and Ranamukhaarachchi, 2011). Application of NP fertilizers at optimum rates might result in superior growth and development that eventually reflected with significantly superior yield attributes (Kumar *et al*., 2017; Riste *et al*., 2017). Inferior crop growth in the controls without NP applications might be closely associated with insufficient availability of NP below their optimal requirements (Riste *et al*., 2017). Kumar et al. (2017) had reported maximum number of total and effective tillers m-^{2} with application of 150 kg N and75 kg P2O5 kg ha^{-1}. On the other hand, Riste et al. (2017) reported maximum number of tillers and panicle m- ^{2}at the rate of 120 kg N and 90 kg P2O5 kg ha^{-1}

Table 2 Combined analysis of N and P fertilizer rates on yield and yield components of transplanted rice in Fogera plain

N level	**PH** (cm)	Pl (cm)	NT/m2	NFP/m2	NFG/p	TGW(g)	AGY (t/ha)	SY (t/ha)	HI (%)
0	85.7d	20.0c	168e	152e	108	30.5	1.86c	4.9d	37.3ba
92	97.8c	21.3b	229d	213d	113	29.6	3.00b	8.1c	37.6ba
184	102.7bc	21.8ba	283c	264c	118	29.6	4.29a	11.3b	37.9a
276	103.8ba	22.1ba	326b	300b	109	30.0	4.29a	12.0b	35.8b
368	108.3a	22.5a	363a	332a	106	29.9	4.56a	13.6a	33.9c
LSD (5%)	***	**	***	***	NS	NS	***	***	***
P levels									
0	100.3	21.7	263	242b	117	30.0	3.38b	9.5b	36.1
23	100.8	21.6	277	260ba	111	29.8	3.57b	9.8b	36.7
46	99.8	21.5	289	263a	107	30.2	3.85a	10.6a	36.8
92	97.9	21.3	266	244ba	107	29.7	3.61ba	10.0ba	36.5
LSD (5%)	NS	NS	NS	NS	NS	NS	**	*	NS
N*P	NS	NS	***	***	NS	NS	NS	NS	NS
CV (%)	9.17	9.55	16.1	16.09	19.1	11.3	13.9	14.4	8.95

PH = *plant* height (cm), PL = panicle length (cm), TT/m^2 = total tillers/m^2, NFP = number of fertile panicles/m^2, NFG/P= number of filled grain per panicle, GY = grain yield (t ha^{-1}), SY = straw yield (t ha^{-1}), TGW=thousand grain weight (g), HI = harvest index (%), *** = very highly significant at P<0.001, highly significant at P<0.01 * = significant at P<0.05, ns = not significant at P≥0.05

Grain Yield

Significantly (P<0.001) variations exhibited between the main effect of nitrogen and phosphorus on grain yield but not their interaction. The highest grain yield (4.56 ton-/ha) was obtained from 368 kg ha-^{1} N followed 276 and 184 kg ha-^{1} N (4.29 and 4.29 ton /ha) respectively, which was statistically similar. (Table 2). While the lowest grain yield (1.86 t/ha) was recorded from, no N (Table 2). **Application of more fertilizer in the crop in different growth stage leads to produce more fertile tillers and grain formation.** The result indicated that the highest grain yield obtained might be attributed to the highest number of total tillers/m^2 and a greater number of fertile panicles per m^2 that cumulatively increased the grain yield. Nitrogen and Phosphorus are fundamental to crop development because they form the basic component of many organic molecules, nucleic acids and proteins (Vinod and Sigrid, 2012). The increase in the grain yield in response to Nitrogen and phosphorus fertilizer could be attributed to the production of more productive tiller and fertile panicle numbers (Azhiri *et al.*, 2004). The results agree with the finding of Amanullah *et al.*, (2016). The higher grain yield may be attributed due to better growth with higher nutrient availability and higher photosynthetic rate of the plants and more photosynthetic partitioning into the reproductive parts. (Fageria and Baligar, 2001; Dong *et al.*, 2016; Gewaily *et al.*, 2018)., reported that nitrogen application increases the grain yield and largest values recorded at the nitrogen application treatment of 209-220kg N ha-^{1}. As opposed to the finding, Liu *et al,* (2019) reported the highest mean grain yield of 10.5 t ha^{-1}obtained from 300 kg ha^{-1} N suggesting that use of 360 kg ha^{-1}; Nitrogen reduced to 9.4 t ha^{-1}. Optimum fertilizer level plays an important role in achieving crops potential yield. Among the fertilizer, N is most important for proper growth and development of rice (Sah *et al.,* 2019). The increase in grain yield might be due to nitrogen application enhancing the dry matter production, improving rice growth rate, promoting elongation of internodes and activity of growth hormones like gibberellins (Gewaily *et al.*, 2018). In contrast, thousand seeds weight was not affected by the main and interaction effect of nitrogen and phosphorous rates.

Straw Yield

The rice straw yield was very highly significantly (P<0.001) affected by the main effect of nitrogen rates but significantly (P<0.05) affected by phosphorus rate but not the interaction of the two rates (Table 2) Significantly higher straw yield (13.6 ton /ha) was obtained from maximum nitrogen rate of (368 kg/ha N) followed by 276 and 184 kg/ha N (12.0 and 11.3 ton/ha) respectively which was statistically similar. The lowest straw yield (4.9 ton/ha) were recorded from Zero N application (Table 2). This might be due to the application of nitrogen fertilizer rate according to crop requirement increased the nitrogen absorption, consequently better utilization of applied nitrogen leads to higher yield attributes and finally resulted in higher grain and straw yields. Moreover, larger plant height, a greater number of total tillers per m^2 and greater panicle length might have contributed to increase in straw yield. This is in agreement with Maragatham, *et al.* (2010) who stated better straw yield could be explained as higher capability of rice to utilize more N through the expression of better growth by accumulating more plant dry biomass. The better grain and straw yields at the higher rates of N and P nutrients may be attributed to the fact that application of fertilizer may have resulted in optimum levels of nutrients for crop uptake and translocation to sink thereby expressing superior crop growth and development (Riste *et al.*, 2017). In support of the present finding, Kumar *et al.* (2017) stated that the grain and straw yields of rice increased up to application of 150:75 N-P^2O^5 kg ha^{-1}. Masni and Wasli (2019) had also reported that the grain and straw yields of upland rice were significantly affected and best at 60N and 35 kg P kg ha^{-1}.

Harvest index

Nitrogen showed a highly significant negative effect on harvest index of rice crop (Table2). As revealed in the analysis of variance harvest index responded highly significantly ($P<0.001$) affected by the main effect of nitrogen and phosphorous fertilizer rates but not by their interaction (Table 2). As indicated in Table 2, harvest index decreased with increasing levels of N and P fertilizer at the maximum rate 368 and 276 kg of N P_2O_5ha-^{1} (Table 2).The highest harvest index, among the nitrogen rates was recorded at 184 kg ha-^{1} N .The lowest Harvest index was recorded at 368 kg ha-^{1} N followed by 276 kg ha-^{1} N (Table 2) Results of a number of similar studies Kumar and Rao, (1992); Patra *et al.*, (1992) and Hari *et al.*, (1997) have also revealed decreasing trends of harvest index with increased rates of applied N fertilizer. They also stated that harvest index in rice is closely related to the percentage of productive tillers which generally decreases with the increase of N fertilizer. Mulugeta Seyoum and Heluf Gebrekidan (2006) had also reported that harvest index consistently declined with increasing levels of applied N up to the highest level 150 kg of N ha^{-1}. On the other hand, application of 13.2 kg P ha^{-1} significantly increased harvest index of rice. Generally, increasing the levels of N fertilizer from 0 to 150 kg ha^{-1} decreased the harvest index of rice from 44.93 to 37.22%.

Partial budget analysis

Based on the principles of economic analysis as per CIMMYT (1988), the minimum acceptable marginal rate of return (MRR %) should be 100%. The economic analysis was done on the basis of the prevailing prices of variable costs using the Ethiopian currency

(Birr). The price of NPS and Urea fertilizer was 1430.00 and 1310.00 Birr per 100 kg, respectively. Moreover, the price of rice straw valued Birr 120.00 per 100 kg. In addition to this, the prices of seed for planting material during the cropping season were 1350.00 Birr per 100 kg. Grain and straw yield adjustments, calculations of total variable costs (TVC), gross benefits (GB) and net benefits (NB) were performed (Table 3). Dominance analysis was performed after arranging the treatments in their order of TVC (Table 3). Treatments are considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB (Table 3). Non dominated treatments were taken out and marginal rate of return (MRR) was computed (Table 3). The economic analysis of the result of this experiment revealed that highest NB (Birr 63928.2 ha^{-1}) with acceptable level of MRR (1677.59) was observed at 184-46 N-P2O5 kg/ha (Table 3). In agreement to the present finding Irfan *et al*., (2016) reported that rice genotypes performed efficiently at 120 kg N + 90 kg P2O5 ha^{-1} where highest paddy yield, net production value and profit were obtained.

Table 3 Effects of N and P fertilizer rates on economic benefit of Transplanted rice in Fogera plain

N kg/ha	P2O5 kg/ha	GY (t/ha)	SY (t/ha)	AGY (t/ha)	ASY(t/ha)	GB (Birr/ha)	TVC (Birr/ha)	NB (Birr/ha)	Dominance	MRR %
0	0	1.74	4.73	1.56	4.26	26228.5	0	26228.5		-
0	23	1.78	4.81	1.60	4.33	26773.6	715	26058.6	D	-
0	46	2.15	5.68	1.94	5.11	32309.3	1430	30879.3		325.23
0	92	1.72	4.53	1.54	4.08	38740.9	2620	36120.9		440.47
92	0	2.57	6.93	2.32	6.23	25747.2	2860	22887.2	D	-
92	23	3.21	8.51	2.89	7.66	48230.2	3158.03	45072.2		1663.73
92	46	3.23	8.47	2.90	7.62	48330.7	3696.05	44634.6	D	-
92	92	3.14	8.36	2.82	7.53	47159.9	4772.11	42387.8	D	-
184	0	3.84	10.35	3.46	9.32	57836.5	5240	52596.5		361.40
184	23	4.05	10.68	3.64	9.61	60680.3	5778.03	54902.3		428.56
184	46	4.71	12.07	4.24	10.86	70244.2	6316.05	63928.2		1677.59
184	92	4.48	11.94	4.03	10.75	67277	7392.11	59884.9	D	-
276	0	4.26	11.71	3.83	10.54	64381.6	7860	56521.6	D	-
276	23	4.03	11.94	3.63	10.75	61845.6	8398.03	53447.6	D	-
276	46	4.57	12.79	4.12	11.51	69380.8	8936.05	60444.8	D	-
276	92	4.26	11.60	3.83	10.44	64279.3	10012.1	54267.2	D	-
368	0	4.47	13.81	4.02	12.43	69187.5	10480	58707.5	D	-
368	23	4.81	13.24	4.33	11.92	72771	11018	61753	D	-
368	46	4.48	14.13	4.03	12.72	69688.1	11556.1	58132	D	-
368	92	4.44	13.39	4.00	12.05	68416.3	12632.1	55784.2	D	-

Nitrogen (kg ha^{-1}); P2O5= Phosphorous rate (kg ha^{-1}); TVC= Total variable cost (Birr ha^{-1}) GY, grain yield (t ha^{-1}) AGY= Adjusted grain yield (ton ha^{-1}); SY= straw yield (ton ha^{-1}) ASY= Adjusted straw yield (ton ha^{-1}); GB= Gross benefit (Birr ha^{-1}); NB = Net benefit (Birr ha^{-1}); D=Dominance analysis and MRR (%) marginal rate of return

Conclusion

Rice is generally established through direct seeding or by transplanting. Direct seeding is the practice of sowing seeds directly in the main field. On the other hand, transplanting is the practice of raising seedlings in a nursery and moving them into the main field. The major advantages of transplanting over direct seeding are better weed suppression and higher grain yield. Transplanted rice matured earlier and escaped terminal moisture stresses than direct seeded rice. Farmers in Fogera plains of northwestern Ethiopia generally establish rainfed lowland rice through broadcast direct seeding. Rice production in the study often faces the problem of terminal moisture stress owing to abrupt ending of rainfall at the reproductive and grain filling stages of the crop.The farmers spend much of their family labour and money on weeding.. Most of the yield components Specially on plant height, number of total tillers per m^2 and number of fertile panicles per m^2, grain yield, straw yield harvest index and panicle length were markedly enhanced in response to transplanting. The findings of the present experiment showed that the highest net benefit of (Birr **63928.2**. ha^{-1}) was obtained from nitrogen and phosphorous fertilizers at rates of 184-46 N- P_2O_5 kg $ha^{-1.}$ The results of two years experiment indicated that combined application of 184-46 N-P2O5 kg ha^{-1} is the best treatment giving higher productivity and economic profitability. It is thus concluded that application of nitrogen and phosphorous fertilizers at rates of 184-46 N P_2O_5 kg ha^{-1} is the best recommended rate for using transplanted method of rice production in Fogera and other similar agroecology in the future.

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