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Effect of Irrigation Scheduling and Fertigation on Leaf Nutrient Content and Uptake of N, P and K of Pomegranate *cv.* Bhagwa under Semi-arid Conditions of Rajasthan

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ABSTRACT: The trial was conducted on pomegranate plants of cv. Bhagwa growing under high density planting system (3 m × 3 m) with three drip irrigation levels, *i.e.*, 100%,75% & 50 % on pan evaporation basis and four fertigation levels, *i.e.*, 100% RDF as basal, 100%, 75% and 50% recommended dose of fertilizer through drip. After field experiment for two consecutive years it is concluded that maximum leaf N and P content (%) was found under the treatment I_3F_3(100% irrigation at PE level + 75 % RDF through drip) whereas maximum Leaf K Content (%) was found under the treatment I_3F_2(100% irrigation at PE level + 100 % RDF through drip). For nutrient uptake, maximum N uptake (kg ha^{-1}) (413.77) was recorded in the treatment I_3F_2 which was found to be statistically at par with I_3F_3, maximum P uptake (kg ha^{-1}) (40.88) was recorded in the treatment I_3F_2 which was found to be statistically at par with I_3F_3, whereas maximum K uptake (kg ha^{-1}) (313.35) was recorded in the treatment I_3F_2 which was found to be statistically at par with I_3F_3.

Keywords: irrigation, Nutrient uptake, leaf nutrient content, fertigation, pomegranate.

INTRODUCTION

Pomegranate (*Punica granatum*) a member of the family Punicaceae is one of the most important fruit crop, which is suitable for growing in arid and semi-arid regions owing to its versatile adaptability, hardy nature, low maintenance and high yield (Banker and Prasad 1992). It is a native fruit of Iran and extensively cultivated throughout India, Iran, China, Turkey, USA, Spain, Azerbaijan, Armenia, Afghanistan, Uzbekistan, Pakistan, Tunisia, Israel, dry regions of Southeast Asia, Peninsular Malaysia, the East Indies and tropical Africa (NRCP Bulletin Solapur, 2014). Pomegranate is grown to a restricted extent in many states of India. Maximum area under this crop is in Maharashtra (Nashik, Solapur, Ahmednagar, Pune, Sangli and Wardha districts) followed by Karnataka (Chitradurga, Bellary, Tumkur, Bijapur, Bagalkot), Gujarat (Kachchh, Banas Kantha, Mehsana). The other states where pomegranate is cultivated are Andhra Pradesh, Rajasthan, Uttar Pradesh, Haryana and Tamilnadu. Irrigation water and nutrients are the most crucial inputs which directly affect the plant vegetative growth, development, yield and quality of product. Application of irrigation water and fertilizers together through drip is the most efficient way of applying water and nutrient to the plant root zone. These inputs are efficiently harnessed by plants as these are placed near root zone of the plant. For proper water management, scheduling of water is beneficial (Tan, 1980). Scheduling of irrigation is the process which helps an irrigator to determine the timing, frequency and quantity of water that is to be applied to the crop. The main task is to estimate crop water requirement in the perspective of growth stages of plant and climate (Tan and Layne 1981). Many scholars have reported about the higher water application efficiency in drip irrigation as compared to the conventional basin irrigation systems Salvin *et al*., (2000); Bharambe *et al*. (2001); Agrawal and Agrawal (2007) in fruits found that there was 40 to 60% more saving of irrigation water through drip system as compared to basin irrigation method.

METHODOLOGY

Leaf Nutrient Analysis:
(i) Leaves N, P and K status (%): To determine the

nutrient status of the plant during the month of June and December, the tenth pair of leaves were collected and a sample of 50 leaves was prepared. After sample collection the fresh leaves were decontaminated from dust and foreign material by washing with the following solutions:

1. 0.2 per cent liquid detergent
2. N/10 HCl solution (8 ml concentrated HCl / liter water)
3. Deionized water

Thoroughly washed samples were dried in oven at 70°C for 72 hrs. then the samples were grinded separately to pass through sieve 40 mesh size. From each sample required quantity of sample in grams was weighed separately for analysis to determine N, P and K content by adopting the following standard methods.

NPK uptake (kg ha^{-1}): The uptake of nitrogen, phosphorus and potassium were computed from their content in leaves using following relationship:

Nutrients uptake by leaves (kg ha^{-1}) =

$$\frac{\text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1})}{100}$$

Table: 1 Analysis of plant leaves.

Content (%)	Method	Reference
Nitrogen	Nessler's reagent colorimetric method	Linder (1944)
Phosphorous	Ammonium vanadomolybdo phosphoric	Richards (1954)
Potassium	Flame photometer method	Richards (1954)

RESULTS AND DISCUSSION

Leaf nutrient status:

Leaf N content (%). As obvious from the table the irrigation levels significantly affected the leaf N content (%) in pomegranate. The maximum leaf N content (1.73 % and 1.83 %) was obtained in treatment I_3 which was found to be statistically at par with I_2 whereas, the minimum leaf N content (1.46 % and 1.61 %) was found under treatment I_1 in 2019-20 and 2020-21 respectively. The maximum leaf P and K content (0.12 % and 0.20 %; 1.22 % and 1.33 %). Pooled data of both the years showed that the maximum leaf N content (1.78 %) was found under treatment I_3 which was found to be statistically at par with I_2 and minimum and 1.53 %) and I_1 respectively.

As presented in the table that fertigation levels significantly affected the leaf N content in pomegranate. The maximum leaf N content (1.64 % and 1.78 %) was obtained in treatment F_3 which was found to be statistically at par with F_2 whereas, the minimum leaf N content (1.54 % and 1.66 %) was found under treatment F_4 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum leaf N content (1.76 %) was found under treatment F_3 which was found to be statistically at par with F_2 and minimum leaf N content (1.60 %) was found under treatment F_4.

Interaction effect (I × F). Interaction effect of drip irrigation levels and fertigation presented in the table showed significant effect on leaf N content (%). Based on the found data, the maximum leaf N content (1.76 % and 1.88 %) was recorded in I_3F_3 treatment combination which was found to be statistically at par with I_3F_2 in year 2019-20 and 2020-21 respectively. However, minimum leaf N content (1.40 % and 1.54 %) was recorded in I_1F_4 treatment combination in year 2019-20 and 2020-21 respectively. Pooled data for both the years showed that maximum leaf N content (1.82 %) was recorded in the treatment I_3F_3 which was found to be statistically at par with I_3F_2 and minimum leaf N content (1.47 %) was recorded in the treatment I_1F_4.

Leaf P Content (%): Irrigation levels significantly affected the leaf P content in pomegranate. The maximum leaf P content (0.12 % and 0.20 %) was obtained in treatment I_3 which was found to be statistically at par with I_2 whereas, the minimum leaf P content (0.09 % and 0.17 %) was found under treatment I_2 and under treatment I_1 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum leaf P content (0.16 %) was found under treatments I_3 which was found to be statistically at par with I_2 and minimum leaf P content (0.14 %) was found under treatment I_1.

As presented in the table that fertigation levels significantly affected the leaf P content in pomegranate. The maximum leaf P content (0.18 % and 0.17 %) was obtained in treatment F_2 which was found to be statistically at par with F_3 whereas, the minimum leaf P content (0.16 % and 0.17 %) was found under treatment F_4 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum leaf P content (0.19 %) was found under treatment F_2 which was found to be statistically at par with F_3 and minimum leaf P content (0.17 %) was found under treatment F_4.

Interaction effect (I × F): Interaction effect of drip irrigation levels and fertigation presented in table showed significant effect on leaf P content (%). Based on the found data, the maximum leaf P content (0.15 % and 0.20 %) was recorded in I_3F_3 treatment combination which was found to be statistically at par with I_3F_2 in year 2019-20 and 2020-21 respectively. However, minimum leaf P content (0.07 % and 0.16 %) was recorded in I_2F_4 treatment combination in year 2019-20 and in I_1F_4 treatment combination in 2020-21 respectively. Pooled data for both the years showed that maximum leaf P content (0.18 %) was recorded in the treatment I_3F_2 which was statistically at par with I_3F_3 and minimum leaf P content (0.12 %) was recorded in the treatment I_1F_4 which was statistically at par with I_1F_2.

Leaf K Content (%): As obvious from the table that irrigation levels significantly affected the leaf K content in pomegranate.

Table 2: Effect of drip irrigation levels and fertigation on leaf N, P and K content (%).

Treatments	Leaf N content (%)			Leaf P content (%)			Leaf K content (%)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Irrigation Levels (I)									
I_1	1.46	1.61	1.53	0.11	0.17	0.14	1.11	1.21	1.16
I_2	1.64	1.75	1.69	0.09	0.19	0.14	1.14	1.24	1.19
I_3	1.73	1.83	1.78	0.12	0.20	0.16	1.22	1.33	1.27
SEm±	0.03	0.04	0.03	0.002	0.004	0.002	0.02	0.03	0.02
CD (5 %)	0.10	0.12	0.08	0.006	0.013	0.007	0.07	0.09	0.05
Fertigation Levels (F)									
F_1	1.63	1.72	1.68	0.09	0.18	0.14	1.18	1.23	1.21
F_2	1.62	1.75	1.69	0.12	0.20	0.16	1.24	1.34	1.29
F_3	1.64	1.78	1.71	0.13	0.19	0.16	1.17	1.28	1.23
F_4	1.54	1.66	1.60	0.08	0.17	0.13	1.05	1.18	1.12
SEm±	0.04	0.05	0.03	0.002	0.005	0.003	0.03	0.04	0.02
CD (5 %)	0.11	0.14	0.09	0.007	0.015	0.008	0.08	0.10	0.06
Interaction (IxF)									
I_1F_1	1.48	1.60	1.54	0.09	0.16	0.13	1.13	1.18	1.16
I_1F_2	1.47	1.63	1.55	0.12	0.18	0.15	1.19	1.29	1.24
I_1F_3	1.49	1.66	1.57	0.13	0.17	0.15	1.12	1.23	1.18
I_1F_4	1.40	1.54	1.47	0.08	0.16	0.12	1.01	1.13	1.07
I_2F_1	1.66	1.74	1.70	0.07	0.18	0.13	1.16	1.21	1.19
I_2F_2	1.65	1.77	1.71	0.10	0.20	0.15	1.22	1.32	1.27
I_2F_3	1.67	1.80	1.74	0.11	0.19	0.15	1.15	1.26	1.21
I_2F_4	1.57	1.68	1.62	0.07	0.17	0.12	1.04	1.16	1.10
I_3F_1	1.75	1.82	1.79	0.11	0.19	0.15	1.24	1.30	1.27
I_3F_2	1.74	1.85	1.80	0.14	0.21	0.18	1.31	1.41	1.36
I_3F_3	1.76	1.88	1.82	0.15	0.20	0.18	1.23	1.35	1.29
I_3F_4	1.65	1.76	1.71	0.10	0.18	0.14	1.11	1.25	1.18
SEm±	0.06	0.08	0.05	0.004	0.009	0.005	0.05	0.06	0.04
CD (5 %)	0.19	0.24	0.15	0.012	0.026	0.014	0.14	0.18	0.11

Table 3: Effect of drip irrigation levels and fertigation on leaf N, P and K uptake (kg ha^{-1}).

Treatments	Leaf N uptake (kg ha^{-1})			Leaf P uptake (kg ha^{-1})			Leaf K uptake (kg ha^{-1})		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Irrigation Levels (I)									
I_1	300.89	313.26	307.08	21.75	32.87	27.31	230.22	235.52	232.87
I_2	360.01	354.29	357.15	18.96	38.23	28.59	251.68	251.14	251.41
I_3	394.55	393.44	393.99	28.45	42.73	35.59	279.35	286.05	282.70
SEm±	7.15	8.39	5.51	0.45	0.91	0.51	5.19	6.19	4.04
CD (5 %)	20.98	24.59	15.71	1.31	2.66	1.44	15.21	18.14	11.50
Fertigation Levels (F)									
F_1	354.33	350.95	352.64	19.55	36.75	28.15	256.16	250.87	253.51
F_2	364.90	376.02	370.46	27.02	43.00	35.01	278.92	287.80	283.36
F_3	363.45	361.56	362.50	28.80	38.61	33.70	258.93	259.88	259.41
F_4	324.57	326.14	325.35	16.85	33.42	25.13	220.99	231.73	226.36
SEm±	8.26	9.68	6.36	0.52	1.05	0.58	5.99	7.14	4.66
CD (5 %)	24.22	28.40	18.14	1.51	3.08	1.67	17.56	20.95	13.28
Interaction (I × F)									
I_1F_1	303.04	310.86	306.95	18.45	31.84	25.14	232.41	229.39	230.90
I_1F_2	312.08	333.06	322.57	25.49	37.25	31.37	253.06	263.16	258.11
I_1F_3	310.84	320.25	315.55	27.17	33.45	30.31	234.92	237.64	236.28
I_1F_4	277.58	288.88	283.23	15.90	28.95	22.43	200.50	211.90	206.20
I_2F_1	362.58	351.58	357.08	16.08	37.02	26.55	254.06	244.60	249.33
I_2F_2	373.40	376.69	375.04	22.22	43.32	32.77	276.64	280.61	278.63
I_2F_3	371.91	362.20	367.06	23.68	38.90	31.29	256.82	253.39	255.10
I_2F_4	332.12	326.71	329.42	13.86	33.67	23.76	219.18	225.94	222.56
I_3F_1	397.37	390.43	393.90	24.13	41.38	32.76	282.00	278.61	280.30
I_3F_2	409.23	418.31	413.77	33.34	48.42	40.88	307.07	319.63	313.35
I_3F_3	407.60	402.22	404.91	35.54	43.49	39.51	285.06	288.62	286.84
I_3F_4	363.99	362.82	363.40	20.80	37.63	29.22	243.29	257.36	250.32
SEm±	14.30	16.77	11.02	0.89	1.82	1.01	10.37	12.37	8.07
CD (5 %)	41.95	49.19	31.41	2.62	5.33	2.89	30.42	36.29	23.01

The maximum leaf K content (1.22 % and 1.33 %) was obtained in treatment I_3, whereas, the minimum leaf K content (1.11 % and 1.21 %) was found under treatment I_1 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum and minimum leaf K content (1.27 % and 1.16 %) was found under treatments I_3 and I_1 respectively.

As presented in the table that fertigation levels significantly affected the leaf K content in pomegranate. The maximum leaf K content (1.24 % and 1.34 %) was obtained in treatment F_2 which was found to be statistically at par with F_1 whereas, the minimum leaf K content (1.05 % and 1.18 %) was found under treatment F_4 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum leaf K content (1.29 %) was found under treatment F_2 which was found to be statistically at par with F_1 and minimum and 1.12 %) was found under treatments and F_4 respectively.

Interaction effect (I × F): Interaction effect of drip irrigation levels and fertigation presented in table showed significant effect on leaf K content (%). Based on the found data, the maximum leaf K content (1.31 % and 1.41 %) was recorded in I_3F_2 treatment combination which was found to be statistically at par with I_3F_3 in year 2019-20 and 2020-21 respectively. However, minimum leaf K content (1.01 % and 1.13 %) was recorded in I_1F_4 treatment combination in year 2019-20 and 2020-21 respectively. Pooled data for both the years showed that maximum leaf K content (1.36 %) was recorded in the treatment I_3F_2 which was found to be statistically at par with I_3F_3 and minimum leaf K content (1.07 %) was recorded in the treatment I_1F_4.

Nutrient uptake (Kg Ha^{-1})

N Uptake (kg ha^{-1}): As obvious from the table that irrigation levels significantly affected the N uptake (kg ha^{-1}) in pomegranate. The maximum N uptake (kg ha^{-1}) **(**394.55 and 393.44) was obtained in treatment I_3 whereas, the minimum N uptake (kg ha^{-1}) (300.89 and 313.26) was found under treatment I_1 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum and minimum N uptake (kg ha^{-1}) (393.99 and 307.08) was found under treatments I_3 and I_1 respectively.

As presented in the table that fertigation levels significantly affected the N uptake (kg ha^{-1}) in pomegranate. The maximum N uptake (kg ha^{-1}) (364.90 and 376.02) was obtained in treatment F_2 which was found to be statistically at par with F_3 whereas, the minimum N uptake (kg ha^{-1}) (324.57 and 326.14) was found under treatment F_4 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum N uptake (kg ha^{-1}) (370.46) was found under treatments F_2 which was found to be statistically at par with F_3 and minimum N uptake (kg ha^{-1})(325.35) was found in treatment F_4.

Interaction effect (I × F): Interaction effect of drip irrigation levels and fertigation presented in table showed significant effect on N uptake (kg ha^{-1}). Based on the found data, the maximum N uptake (kg ha^{-1}) (409.23 and 418.31) was recorded in I_3F_2 treatment combination which was found to be statistically at par with I_3F_3 in year 2019-20 and 2020-21 respectively. However, minimum N uptake (kg ha^{-1}) (277.58 and 288.88) was recorded in I_1F_4 treatment combination in year 2019-20 and 2020-21 respectively. Pooled data for both the years showed that maximum N uptake (kg ha^{-1}) (413.77) was recorded in the treatment I_3F_2 which was found to be statistically at par with I_3F_3 and minimum N uptake (kg ha^{-1}) (283.23) was recorded in the treatment I_1F_4.

P Uptake (Kg Ha^{-1}): As obvious from the table that irrigation levels significantly affected then pomegranate. The maximum P uptake (kg ha^{-1}) (28.45 and 42.73) was obtained in treatment I_3, whereas, the minimum P uptake (kg ha^{-1}) (18.96 and 32.87) was found under treatment I_2 in 2019-20 and under treatment I_1 in 2020-21 respectively. Pooled data of both the years showed that the maximum and minimum P uptake (kg ha^{-1}) (35.59 and 27.31) was found under treatments I_3 and I_1 respectively.

As presented in the table that fertigation levels significantly affected the Leaf P uptake (kg ha^{-1}) in pomegranate. The maximum P uptake (kg ha^{-1}) (28.80 and 43.00) was obtained in treatment F_3 and F_1 in 2019-20 and 2020-21 respectively, whereas, the minimum P uptake (kg ha^{-1}) (16.85 and 33.42) was found under treatment F_4 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum P uptake (kg ha^{-1}) (35.01) was found in treatment F_2 which was found to be statistically at par with F_3 and minimum P uptake (kg ha^{-1}) (25.13) was found under treatment F_4.

Interaction effect (I × F): Interaction effect of drip irrigation levels and fertigation presented in table showed significant effect on P uptake (kg ha^{-1}). Based on the found data, the maximum P uptake (kg ha^{-1}) (35.54 and 48.42) was recorded in I_3F_3 treatment combination in year 2019-20 and in I_3F_2 treatment combination in year 2020-21 respectively. However, minimum P uptake (kg ha^{-1}) (13.86 and 28.95) was recorded in I_2F_4 treatment combination in year 2019-20 and in I_1F_4 treatment combination in year 2020-21 respectively. Pooled data for both the years showed that maximum P uptake (kg ha^{-1}) (40.88) was recorded in the treatment I_3F_2 which was found to be statistically at par with I_3F_3 and minimum P uptake (kg ha^{-1}) (22.43) was recorded in the treatment I_1F_4.

K Uptake (kg ha^{-1}): As obvious from the table that irrigation levels significantly affected the K uptake (kg ha^{-1}) in pomegranate. The maximum K uptake (kg ha^{-1}) (279.35 and 286.05) was obtained in treatment I_3, whereas, the minimum K uptake (kg ha^{-1}) (230.22 and 235.52) was found under treatment I_1 in 2019-20 and 2020-21 respectively. Pooled data of both the years showed that the maximum and minimum K uptake (kg ha^{-1}) (282.70 and 232.87) was found under treatments I_3 and I_1 respectively.

As presented in the table that fertigation levels significantly affected the K uptake (kg ha^{-1}) in pomegranate. The maximum K uptake (kg ha^{-1}) (278.92 and 287.80) was obtained in treatment F_2, whereas, the minimum K uptake (kg ha^{-1}) (220.99 and 231.73) was found under treatment F_4 in 2019-20 and 2020-21

respectively. Pooled data of both the years showed that the maximum and minimum K uptake (kg ha^{-1}) (283.36 and 226.36) was found under treatments F_2 and F_4 respectively.

Interaction effect (I × F): Interaction effect of drip irrigation levels and fertigation presented in table showed significant effect on K uptake (kg ha^{-1}). Based on the found data, the maximum K uptake (kg ha^{-1}) (307.07 and 319.63) was recorded in I_3F_2 treatment combination which was found to be statistically at par with I_3F_3 in year 2019-20 and 2020-21 respectively. However, minimum K uptake (kg ha^{-1}) (200.50 and 211.90) was recorded in I_1F_4 treatment combination in year 2019-20 and 2020-21 respectively. Pooled data for both the years showed that maximum K uptake (kg ha^{-1}) (313.35) was recorded in the treatment I_3F_2 which was found to be statistically at par with I_3F_3 and minimum K uptake (kg ha^{-1}) (206.20) was recorded in the treatment I_1F_4.

DISCUSSION

It is apparent from the data presented that irrigation levels and fertigation levels significantly affected the leaf N, P and K status. The present study clearly showed that F_2 treatment (100 % RDF through drip) found to be superior with respect to leaf N, P and K status. Maximum values of these were found in F_2. Koo (1984) found that in orange, fertigation increases the leaf nitrogen content. Shirgure *et al*. (2001) found that in acid lime, the per cent increase in leaf nitrogen content was more in case of fertigation of 80 per cent nitrogen followed by nitrogen fertigation of 100 per cent. Similar results in banana were reported by Hegde and Srinivas (1991). In Starking Delicious apple trees treated with four nitrogen fertigation treatments in drip irrigation, significantly lower leaf nitrogen content was found under the treatment receiving lowest nitrogen fertigation (Klein *et al*., 1989). Chauhan and Chandel (2008) experimented with four fertigation levels in kiwifruit and reported that leaf nutrient content (N, P, K) were significantly higher under fertigation with recommended dose of N, P and K. Similar findings were observed by Meena *et al.* (2018) in pomegranate.

Further, under this experiment, higher level of drip irrigation significantly improved N, P and K content in pomegranate leaves. Drip irrigation at regular intervals provides a constant moisture regime in the rhizosphere and therefore facilitates roots to remain moist and active for a longer duration. Continuous moisture in the root zone also increases the proper availability of nutrients and translocation of food which hastens the vegetative growth of the plants. Hegde and Srinivas (1991) observed that in banana plants, increased nitrogen and potassium uptake was observed under drip irrigation. Optimum moisture availability in the root zone may minimize the fluctuations in nutrient concentration and thereby increasing the availability of nutrients to plants and preventing their leaching below the root zone. Rana *et al*. (2005) found that leaf N, P and K content in leaves of peach were influenced significantly by drip irrigation levels with varying discharge rate of one, two and three litre of water per day and observed that higher levels of irrigation increased the percent nitrogen, leaf phosphorus and potassium content of peach. Percent leaf nutrient content (N, P, K, Mg and Ca) in aonla was found maximum in treatment receiving alternate day drip irrigation and was minimum under conventional irrigation method (Chandra and Jindal 2001).

Likewise, the interaction between irrigation levels and fertigation levels were found to be considerably superior to their individual effects. Srinivas (1997) found that 100g N $plant^{-1}$ applied through drip resulted in higher nutrient uptake (N, P and K) compared to direct application of fertilizers.

CONCLUSION

From the above discussion, it may be concluded since treatment I_3F_2 (100% irrigation at PE level + 100 % RDF through drip) was found the best among all the treatment combinations, as it recorded maximum nutrient content (%) as well as maximum nutrient uptake (kg/ha.).

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Conflict of Interest. None.

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