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Effect on Yield and Yield Components of Different Irrigation Levels in Edible Seed Pumpkin Growing

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Abstract—Edible seed pumpkin (*Cucurbita pepo* L.) is one of the important edibles preferred by consumer in Turkey due to its higher nutrient contents. However, there is almost very few study on water consumption and irrigation water requirement of confectionary edible seed pumpkin in Turkey. Therefore, a 2-year study (2013-2014) was conducted to determine the effects of irrigation levels on the seed yield and yield components of drip-irrigated confectionary edible seed pumpkin under Turkey conditions. In the study, the experimental design was made in randomized blocks with three replications. Treatments consisted of five irrigation water levels that compensated for the 100% (I_{100}, full irrigation), 75% (I_{75}), 50% (I_{50}), 25% (I_{25}) and 0% (I_0, no irrigation) of crop water requirements at 14-day irrigation intervals. Seasonal evapotranspiration of treatments varied from 194.2 to 625.2 mm in 2013 and from 208.6 to 556.6 mm in 2014. In both years, the highest seasonal evapotranspiration was obtained in I_{100} treatment. Average across years, the seed yields ranged between 1090 (I_{100}) and 422 (I_0) kg ha^{-1}. The irrigation treatments were found to significantly affect the yield parameters such as the seed yield, oil seed yield number of seeds per fruit, seed size, seed width, fruit size, fruit width and fruit index.

Keywords—Irrigation level, edible seed pumpkin, seed quality, seed yield.

I. Introduction

PUMPKIN is a kind of vegetable grown all over the world as a human food for its fruit and seeds [1]. Pumpkin's fruit, flowers, and seeds are used freshly. The pumpkins differ from each other according to color and the length of the fruit.

Although pumpkin is generally grown for its fruit, its seeds have appetizer value and contain high quality oil [2]. Besides, the oil which is obtained from the edible pumpkin seeds with high nutritional value is used as salad oil some of the countries such as Austria, Slovenia, and Hungary [3]. In some countries, similarly, pumpkin seed oil is consumed in soups and as ingredient in minced meat and also as frying oil [4]. Pumpkin seed oil is used in medicine and diet as well as quality cooking oil [5], [6]. It is stated that pumpkin oil prevents prostate cancer and it is also heart-friendly [7]. For this reason, it is said that eating 70-80 gram of pumpkin seeds a day is beneficial in terms of health [8].

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Pumpkin is important vegetable species in recent years because it has increasing demands in markets. Besides harvest is done by machine and has fewer problems in growing [9]. When cultivation fields and regions of spreading are considered, it is seen that they are generally the fields where arable crops are grown; thus, edible pumpkin is grown in barren or less irrigated fields and have a specific importance.

Konya plain has about 10% of agricultural lands in Turkey and it is known for its arid climate and limited water resources. Its annual rainfall is 323 mm and during the growing season, it ranges between 90 and 100 mm. Irrigation is absolutely needed in these kinds of agricultural lands for a variety of crop production, and to provide the increase of quality and productiveness [10]. In Konya plain, sources of groundwater are generally used as irrigation water and the groundwater level decreases swiftly since the irrigation that is applied above allowed limit, so the quality of the water is impaired. Because of the over drafting of the groundwater - in Konya Plain, the level of the groundwater decreased about 14-15 mm in the last 33 years (1974-2007). About 10-11 m. of this decrease in water level occurred in ten-year period between 1997 and 2007 [11]. In such regions with similar climate characteristics, it has become necessity to use the water efficiently. In order to sustain the agriculture, it is important to avoid cultivation of the types that consume too much water and the types with less water consumption should be grown instead. Accordingly, cultivation of pumpkin as edibles seems to be a suitable type for this region when marketing value and water consumption are considered.

In this study, it was aimed to determine the effect of different irrigation levels on the yield and yield components of pumpkin at 14-day irrigation interval during 2013 and 2014 growth season.

II. Material and Methods

The research was carried out between 2013 and 2014 in experimental field of Agricultural Faculty of Selcuk University, Konya, Turkey. It is located at 38° 02'N latitude, 32° 30′E longitude and 1105-m altitude.

Related to experimental field; organic materials, pH, soil texture, bulk density, the field capacity, and wilting point and the values of available water holding capacity (0-90 cm) are all shown in Table I. As it is seen in Table I, the soil texture is sandy and clay-loamy soil. The values of bulk density are 1.38 - 1.42 g cm^{-3}, moisture values in field capacity ranges between 28.5% and 30.1% by volume percent, and the available water holding capacity (0-90 cm) in 0-90 cm is 126.3 mm. It is also seen that in 0-90 cm soil depth, PH ranges between 7.78 and

7.82 and organic substance ranges between 0.35% and 1.74%. The lands of this experimental field do not limit the cultivation of edible pumpkin in terms of its physical and chemical characteristics.

TABLE I
PHYSICAL AND CHEMICAL PROPERTIES OF THE EXPERIMENTAL SITE SOIL

Soil depth (cm)	pH	Organic Materials (%)	Texture class	Bulk density (g cm^{-3})	Field Capacity (*FC*)		Wilting Point (*WP*)		Available Soil Water Content	
					cm^3cm^{-3}	mm	cm^3cm^{-3}	mm	cm^3cm^{-3}	mm
0-30	7.78	1.74	SCL	1.41	0.285	85.4	0.149	44.8	0.135	40.6
30-60	7.82	1.17	SCL	1.38	0.301	90.3	0.160	48.0	0.141	42.2
60-90	7.82	0.35	SCL	1.42	0.285	85.6	0.141	42.2	0.145	43.5
			Total (0-90 cm)			261.3		135.0		126.3

SCL: Sandy clay loam

TABLE II
VARIATIONS OF METEOROLOGICAL PARAMETERS OF REGION DURING EXPERIMENTAL YEARS

Months		Mean max. temp. (ºC)	Mean min. temp. (ºC)	Mean wind speed (m s^{-1})	Mean Relative humidity (%)	Precipitation (mm)	Mean solar radiation (MJ m^{-2} day^{-1})	Mean daily sunshine (h)
May	2013[a]	25.2	11.4	2.2	59.8	46.6	23.5	7.8
	2014[b]	24.4	8.3	2.0	57.5	7.4	24.3	8.5
	53 years	22.2	8.5	2.2	55.9	43.8	25.0	8.5
June	2013	28.4	14.4	2.9	47.8	8.8	25.8	10.6
	2014	26.4	12.5	2.6	55.9	55.6	24.9	9.3
	53 years	26.6	12.7	2.5	48.4	22.9	27.8	10.4
July	2013	29.5	17.3	3.3	40.1	0.8	27.2	11.1
	2014	32.0	16.7	3.2	44.3	9.6	27.7	11.3
	53 years	30.0	15.9	2.8	42.1	6.8	28.7	11.4
August	2013	30.0	17.1	3.0	39.4	-	26.1	11.2
	2014	32.4	17.5	3.1	43.5	2.8	24.9	11.1
	53 years	29.9	15.4	2.6	42.9	5.5	26.6	11.1
September	2013[c]	25.2	11.2	2.3	47.6	3.0	18.7	9.7
	2014[c]	27.0	12.6	2.1	58.1	8.2	18.5	9.4
	53 years	26.0	11.0	2.1	48.0	11.0	22.1	9.4
Seasonal Average/ Total	2013	27.7	14.3	2.7	46.9	59.2	24.3	10.1
	2014	28.4	13.5	2.6	51.9	83.6	24.1	9.9
	53 years	26.9	12.7	2.4	47.5	90.0	26.0	10.2

[a] Calculated from the data between 10 and 31 May
[b] Calculated from the data between 12 and 31 May
[c] Calculated from the data between 1 and 24 September

The meteorological parameters (air temperatures, relative humidity, wind speed, and solar radiation) were recorded by an automatic weather station (Davis Vantage Pro2) in the experimental area (Table II). The climatic data of the working years show similarities with average climatic data received from long-term (53 years).

The local population named “Ürgüp Sivrisi’’ which is commonly grown in Turkey was used in the research. It is a local genotype which is grown as edibles especially in Central Anatolia Region. In general, the seeds obtained from Ürgüp Sivrisi are 20-22 mm length, narrow, long, their edges are thick and they are easy to crack.

In the study, the experimental design was made in randomized blocks with three replications. Treatments consisted of five irrigation water levels that compensated for 100% (I_{100}, full irrigation), 75% (I_{75}), 50% (I_{50}), 25% (I_{25}) and 0% (I_0, no irrigation) of crop water requirements at 14-day irrigation intervals.

The irrigation water was provided from the water delivery system in Selcuk University Campus. The quality of the irrigation water was determined as C_2S_1 according to the graphic system of the U.S.A Salinity Laboratory [12].

The irrigation water was applied by a drip irrigation system. The system was designed as per the soil and plant properties prior to being installed in the field. Lateral pipes were installed in each row (1.0 m apart) at a distance of about 5–10 cm from the stem. The lateral lines had in-line compensating drippers, and the discharge rate was 4 L h^{-1} at a pressure of 100 kPa. The dripper spacing was chosen to be 0.33 m taking into account the characteristics of soil. Each plot was connected by the flow meter so as to deliver the desired amount of water.

Three pumpkin seeds were planted in each hole that was dug on the line in 1.0x0.5 planting distance in 10 May 2013 and 12 May 2014. After germination, pumpkin seedlings were thinned to one seedling per hole when four leaves were fully grown. A lateral pipe was placed on the planting row and a space of 2.5 m was given between the blocks and parcels. To ensure uniform germination and emergence, after sowing, the irrigation water volume of 33 and 42 mm in 2013 and 2014, respectively. During this period, 5 kg N (nitrogen), 5 kg P_2O_5 (phosphor) and 5 kg K_2O (potassium) were given to as pure substance in drip irrigation method. Necessary cultural precautions were taken to fight with the illnesses and insect pests in times of need in each testing year. Just before the harvest, the edge influence sections of the test parcels were drawn out and fruit was harvested manually on the 24th of September in both testing years.

Soil moisture content in root zone of the plants was measured by gravimetric soil moisture measuring method. Soil moisture measuring was carried out in 0-30, 30-60, 60-90 and 90-120 soil depths during sowing, before each irrigation and in fruit harvest. For measuring the amount of irrigation water that was employed for testing issues, (1) and (2) were used. In order to determine the amount of irrigation water, decreasing soil moisture in 0-90 cm root area was taken into account in 14-day irrigation interval. Irrigation water that was applied to parcels was determined as liter multiplying irrigation water calculated as depth (d_n) in (1) by parcel area (m^2), the percentage of wetted area (P) and irrigation level (IL) (2). Irrigation water that was given to each parcel was measured by water counter at the beginning of the parcels.

$$d_n = \frac{(TK_v - MN_v) \times D}{10} \quad (1)$$

d_n: Irrigation water as depth (mm); TK_v: soil moisture in field capacity as volume percentage (%); MN_v: current soil moisture as volume percentage about I_{100} testing issue in mentioned irrigation interval (%); and finally D is*:* the depth of root area (90cm).

$$I = d_n \times A \times P \times IL \quad (2)$$

I: The amount of irrigation water as volume (liter); d_n: Irrigation water as depth (mm); A: = parcel area (m^2); P: Percentage of wetted area (calculated as %65 [13]; and IL is Irrigation level related to treatments (I_{100}=1.00; I_{75}=0.75; I_{50}=0.50; and I_0=0.00 factors were used)

Plant water consumption for testing issues was calculated on the basis of water budget (3) [14]:

$$ET = I + R - D_P + C_P - R_f \pm \Delta S \quad (3)$$

ET: Crop water consumption (mm); I: The amount of irrigation water that was applied (mm); R: Effective rainfall (mm); D_p: Water loss by deep percolation-(mm); C_p: capillary rise from the beneath of the root region (mm); R_f: Loss of runoff (mm); and ΔS is the change of water content in soil profile (mm).

In equality, I was calculated from the amounts of applied irrigation water; R value from portable climate station set up in testing area; D_p value was calculated by gravimetric method from soil samples taken by gimlet before and after irrigation in 90 and 120 cm deep. In the test, a percolation of water through the 90 cm soil stratum was not observed. Testing area consisted of unproblematic soils in terms of depth, drainage and saltiness. For this reason, because there was no rising of water generating from groundwater C_p value was not taken into account in calculations. ΔS, was obtained from soil moisture measurements in cultivation and fruit harvest. Because drip irrigation system was planned and processed properly, there was no loss of runoff, so R_f value was ignored in calculations.

Water Use efficiency (WUE), which was also expressed as the ratio of unit water utilization and a key criterion in evaluations of irrigation programs, and Irrigation Water Use Efficiency (IWUE) were determined according to [15].

Analysis of variance (ANOVA) was conducted to evaluate the effects of treatments on yield and quality parameters. Duncan's multiple range tests were used to compare and rank the treatment means. Differences were declared significant at $P < 0.05$ or 0.01 [16], [17]. Duncan tests and analysis of variance were performed by using SPSS 16.0 packaged software.

III. Results and Discussion

A. Irrigation Water and Crop Water Consumption

Seasonal irrigation numbers, applied irrigation water, -rainfall, plant water consumption and I_{rc} (the percentage of irrigation water to meet plant water consumption) values were given Table III. Treatments were given water totally 6 times apart from germination irrigation (33 mm in 2013 and 42 mm in 2014). The irrigation schedule was started on the 12th of June in both years and by applying water 48 mm in 2013 and 30 mm in 2014 to all treatments, apart from I_0 (no irrigation) treatment, soil moisture that was in 0-90 cm depth plant root depth was upgraded to field capacity. The sequential irrigation was performed in 14-day intervals. Irrigation was ended on the 28th of August in both years and from that day on there was not irrigation until harvest (24th September). The highest irrigation water was given to I_{100} treatment that was applied water to make decreased soil moisture in 0-90 cm every time reach field capacity. Related to the I_{100} treatment, 489 and 409 mm irrigation water was given in 2013 and 2014, respectively. Depending on the treatments, the amount of applied water decreased as the limit level increased.

Rainfall during pumpkin vegetation period was 59.2 and 83.6 mm in 2013 and 2014, respectively. In both years, most of the rainfall during vegetation period was between the dates of plantation of the seeds (10th and 12th May) and the beginning of programmed irrigation (12th June). Because testing field was flat and rainfall could never increase the soil moisture in the root zone over the field capacity, all rainfall that was measured in plant water consumption was considered as effective rainfall. Plant water consumption ranged between 194.2 and 625.2 in 2013; it also changed between 208.6 and 556.6 in 2014.

The highest plant water consumption was calculated in I_{100} testing issue where plant water need was met %100 in both testing years. I_{rc}, which is described as percentage of irrigation water to meet plant's water consumption and it ranged between 17-78% in 2013 and 20-73% in 2014 depending on testing topics. The more amount of applied irrigation water decreased, the more Irc values decreased. In his study to compare furrow and drip irrigation for summer pumpkin, stated that water consumption of pumpkin changed between 238 and 344 mm depending on irrigation methods and tests years [18]. Found water consumption of summer pumpkin and edible pumpkin as 413 and 408, respectively. In their studies which they conducted in Van, gave irrigation water of 279 and 475 mm to pumpkin to determine performance parameters depending on the testing issues [19]. As a result of the research, they reported that water consumption of testing issues changed between 336 and 539 mm. In the one study carried out a 3-year study in Thracian conditions to determine the effect of limited irrigation to seed performance in different phonological periods of edible pumpkins [20]. As phonological periods, the terms of (A) seeing the first blossoms, (B) developing of fruits (about 20 days later after blossom) and (C) originating of the seeds (about 40 days later after blossom) were considered. When the average of testing years is considered, the most irrigation water was given to ABC issue that was watered in each three periods with the amount of 394.5 mm.

TABLE III.
IRRIGATION APPLIED AND ET_A IN DIFFERENT YEARS AND TREATMENTS

Years	Treatments	Number of irrigation	Irrigation applied (mm)	Effective rainfall (mm)	ΔS (mm)	ET_a (mm)	I_{rc} (%)
2013	I_{100}	6	489	59.2	77	625.2	78
	I_{75}	6	387	59.2	84	530.2	73
	I_{50}	6	285	59.2	86	430.2	66
	I_{25}	6	183	59.2	102	344.2	53
	I_0	-	33	59.2	102	194.2	17
2014	I_{100}	6	409	83.6	64	556.6	73
	I_{75}	6	324.8	83.6	79	487.4	67
	I_{50}	6	240.5	83.6	86	410.1	59
	I_{25}	6	156.3	83.6	90	329.9	47
	I_0	-	42	83.6	83	208.6	20

The data obtained from the current study was higher than the data found in previous studies in terms of both the amount of irrigation water and plant water consumption. It is considered that the differences between them result from the features like climate, type, soil that were used etc. Besides, the number of the studies on water management in edible pumpkin is low in scientific literature, so the literatures given here are mostly related to water consumption of summer pumpkin. Generally, the vegetation period of summer pumpkin is 30-40 days shorter than edible pumpkin, so its water consumption is lower.

B. Performance and Quality Parameters

In Konya conditions, the seed yield, seed oil ratio, oil yield, the number of seeds per fruit, WUE and IWUE values were given at Table IV; the length of seed, the width of seed, seed index, the length of fruit, the width of fruit and fruit index were given at Table V. Whether total statistical analysis would be done to the data of each testing year or not was tested by analysis of variance (ANOVA). As a result of the tests, it was seen that the data obtained from the both testing years was not homogeneous on the basis of years. For this reason, each year was studied separately while the features of performance and quality were being evaluated.

When Table IV was examined, it was seen that the highest seed yield (for 118.2 kg da^{-1}) was attained in I_{100} testing subject in 2013 and statistically there was not any difference from I_{75}, treatment -with 99% reliance- according to the results of Duncan's multiple range tests. In 2014, when scrutinizing in terms of seed performance, I_{100} gave the highest performance (99.7 kg da^{-1}) and I_{75} (81 kg da^{-1}) took part in the same group. In different edible pumpkin studies performed in Konya conditions, it was stated in studies that seed performance 40-134 kg da^{-1} [21], 20- 97 kg da^{-1} [1], and 23-139 kg da^{-1} [9]. In his study to determine the effects of row spacing to seed performance for edible pumpkin, [22] got the highest seed performance (110 kg da^{-1}) on the condition of 4 plants in m$^{2.}$ In the research carried out by [23], in Iran, the highest seed performance was attained in the issues that were watered once every seven days and 97 kg/da. The same researchers stated that the most suitable irrigation interval was 7-day and row spacing and intra-row distance were 100 x 40 for edible pumpkin agriculture. Expressed that there would be a significant decrease in performance when pumpkin was overwatered or deficiently watered [18]. It was seen that they got parallel results with the studies when evaluating the highest performances.

When the seed-oil yield was analyzed, it was statistically important in 2013 and 2014. I_{100} irrigation treatment gave the highest oil performance with 42.7 kg/da and 35.5 kg/da respectively. In parallel with this, oil ratio was obtained as 35-36% from the same issue. The seed number for each fruit did not make any difference among the first year applications but in the second year the applications apart from 10 was in the same group. However, the most number of seeds per fruit were obtained in 2013 as 279; and in 2014 as 237. In a rehabilitation work conducted in our country, genotypes of different kinds were determined and it was stated that they contained oil between 22% and 39% [21]. In a different study in Iran, they announced that genotypes of edible pumpkin were between 36% and 47% [24]. The reason why our results were lower than the conducted studies resulted from the use of different population types. It was seen, by the way, the limitation of irrigation didn't have any influence on the oil content.

TABLE IV
THE RESULTS RELATED TO SEED YIELD, OIL RATIO, OIL YIELD, NUMBER OF SEEDS PER FRUIT, WUE AND IWUE

Years	Treatments	Seed yield kg/da	Oil yield kg/da	Oil ratio %	Number of seeds per fruit	WUE (kg m^{-3})	IWUE (kg m^{-3})
2013	I_{100}	118,2a	42,7a	36,2	278,8	0,19b	0,24c
	I_{75}	113,5a	39,8ab	34,5	298,4	0,21b	0,29c
	I_{50}	87,1ab	29,3bc	33,8	253,9	0,20b	0,31c
	I_{25}	80,4ab	28,7bc	35,7	237,5	0,23b	0,44b
	I_0	62,4b	21,1c	33,9	243,7	0,32a	1,89a
	Significance	**	*	ns	ns	**	**
2014	I_{100}	99,7a	35,5a	35,5	237,5a	0,18	0,24b
	I_{75}	81,0ab	27,1ab	33,6	220,7a	0,17	0,25b
	I_{50}	56,8bc	20,1b	35,0	186,3ab	0,14	0,24b
	I_{25}	45,4cd	15,0bc	32,9	185,2ab	0,14	0,29b
	I_0	22,0d	7,7c	34,9	163,2b	0,11	0,52a
	Significance	**	**	ns	**	ns	**

ns: statistically insignificant according to $P<0.01$ and $P<0.05$. **: statistically significant according to $P<0.01$. *: statistically significant according to $P<0.05$

TABLE V
THE SEED AND FRUIT DIMENSIONS

Years	Treatments	Seed size (mm)	Seed width (mm)	Seed index	Fruit size (mm)	Fruit width (mm)	Fruit index
2013	I_{100}	20,2	8,8	2,30	180,2a	156,2	1,16
	I_{75}	20,3	9,0	2,26	169,7ab	169,6	1,00
	I_{50}	19,3	8,5	2,26	171,5ab	155,1	1,11
	I_{25}	19,5	8,4	2,33	151,5b	152,4	1,01
	I_0	19,2	8,5	2,26	147,4b	132,3	1,11
	Significance	ns	ns	ns	*	ns	ns
2014	I_{100}	19,7	9,2	2,15	162,5a	156,8a	1,04
	I_{75}	20,5	8,1	2,55	153,8a	147,4a	1,05
	I_{50}	20,0	9,1	2,19	148,7ab	150,1a	0,99
	I_{25}	19,9	8,7	2,28	144,5ab	127,6b	1,14
	I_0	17,7	8,4	2,10	126,4b	113,2b	1,12
	Significance	ns	ns	ns	**	**	ns

Water use efficiency (WUE) was between 0.19 and 0.32 in 2013; and in 2014 was between 0.11 and 0.18. Although the highest WUE value was obtained in I_0 (no irrigation) testing issues in 2013, in 2014 the highest WUE was in I_{100} testing issue (Table IV). It was thought that different WUE values obtained between testing years resulted from climatic characteristics. Especially in 2014, the high temperature and low relative humidity in fruit set period reduced the seed performance in treatments. And this caused the decrease of WUE value that was attained in treatments in 2014. Irrigation water use efficiency (IWUE), which was an important factor in the evaluation of irrigation programs, ranged between 0.24 and 1.89 kg m^{-3} in 2013; and between 0.24 and 0.52 in 2014. In both testing years, the highest IWUE value was calculated in I_0 testing subject. Generally, in many studies performed to determine water-performance relationship WUE and IWUE values have parallels with each other. However, in this test IWUE values were high in the issues that were not irrigated. The reason is that nearly 30-40 kg da^{-1} seed yield was obtained in the I_0 treatment.

As it is seen in Table V, the seed size changed between 19 and 20 mm, the seed width changed between 8.1 and 9.2 mm, seed index with a change between 2.1 and 2.5 mm; and the fruit size changed between 126.4 and 180.2 mm, the fruit width changed between 113.2 and 169.6 mm, and fruit index with a change between 0.99 and 1.16 mm when both testing years were evaluated together. In a study about edible pumpkin, they declared that the fruit size was 15-30 mm, the size of the fruit was 14-28 mm, and fruit index was 0.6-2.2 mm [25]. And in a study in the region about edible pumpkin, they stated that the length of seed was between 18-23 mm, the width of seed was 10-14 mm, and seed index was between 1.5-2.07 [26]. The results showed similarity with the studies that were performed.

IV. CONCLUSION

When Konya Plain is considered, edible pumpkin agriculture is done in limited irrigation conditions and barren lands. As a result of the implementations with limited irrigations, it was observed that there were four times increase in productivity between full irrigation issue and non-irrigated issue. As a result of this two-year study, it is important to meet whole plant water need of edible pumpkin in terms of high seed performance in 14-day irrigation intervals. However, it is very important to use irrigation water economically in the regions with limited water source like Konya. In such areas, it has become a necessity to cut down the water for many plants. In this context, in the regions with similar climate characteristics of Konya, it is an important factor to meet 75% of plant water need for edible pumpkin agriculture in 14-day irrigation interval because of water saving. The information obtained from the study is thought to be useful for the researchers who can work about the subject in the future and for the irrigation organizations; and also for the farmers who do edible pumpkin agriculture in the regions with limited irrigation conditions.

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