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Effect of Three Weeks of Drying After Terminating Water Uptake at Different Times on Seed Germination in Some Cereals

Mustafa Yildirim[1], Ziya Dumlupinar[2]

[1]*Kelkit Aydin Dogan Vocational School, Gumushane University, Gumushane, Turkey*
[2]*Agricultural Faculty, University of Sutcu Imam, Kahramanmaras, Turkey*

***Abstract*-- Arid and semi-arid regions may experience extended dry periods with little or no precipitation, which can cause winter cereal seeds that have already begun to germinate (and to draw water from the soil) to dry and wither. Even in the event that rains resume after an extended period of dryness, it is generally observed that most, if not all, of the dried seeds are unable to draw water and germinate once again. This phenomenon related to the drying of germinating seeds is called "alatav" in Turkish. This study was conducted to identify the first water uptake rates (WU) of three cereal species and their genotypes (the Gerek and Sultan genotypes of bread wheat, the Kunduru and Dumlupinar genotypes of durum wheat, and the Karma and Presto genotypes of triticale) for a period of 50 hours, and to determine their germination rates (GR) at the second water uptake after the seeds are dried for three weeks. The GR value of the Dumlupinar genotype remained above 0% for the longest period (until the 40th hour, at which time the WU was 64.3%); it was followed by the Kunduru and Gerek genotypes (WU value of 78.2% at 37th hour and 86.5% at the 36th hour, respectively). There was a negative correlation between WU and GR (r = –0.7545*) for all of the genotypes. Therefore, the relationship between GR and WU is a considerable importance for improving our understanding of cereals species' and their genotypes' response and resistance to alatav.**

***Keywords*-- Alatav, cereals, germination, time, water uptake**

I. INTRODUCTION

According to recent estimations, nearly 25% of all agricultural areas across the world are exposed to water stress [1]. For the germination [1, 2, 3, 4] and early development periods [5, 6, 7] of cool-climate cereals grown in these areas, one of the most important limiting factors is water [2]. The often irregular and limited amount of rain in semi-arid climates can adversely affect the germination of seeds [8]. The timing of sowing the crops in such regions is therefore important [9]. For this reason, farmers generally plant their seeds in either dry soil before the first [10] or in heavy and moist soils after the first rain. After the first rain, seeds planted in dry soil will begin to absorb water and expand within a few hours.

However, in case there are no additional rains, and the weather remains dry and warm (thus increasing soil evaporation), these seeds will not be able to continue absorbing water. When seeds are planted after the first rain, the seeds will begin to rapidly absorb water from the moist soil. However, the lack of further rains and continued warm and dry weather can also stop the expansion and growth of seeds planted after the first rain. In both of these planting methods, seeds whose germination is interrupted by adverse weather conditions will remain within the soil in a swollen, partly germinated or dry state [11], for a period of time that may last for weeks, or even months. In certain cases, seeds that have absorbed water and expanded can begin to rot due to soil fungi [12]. These adverse environmental conditions that affect the germination of seeds after their initial water uptake and growth are called "*alatav*" in Turkish. This phenomenon, which can be observed in all semi-arid regions across the world, has the potential to prevent the germination of seeds in many fields across Turkey, and to thereby cause significant losses in yield.

Germination is one of the most important stages in the life of a plant; it is also the period that serves as the first indication of a plant's vigor and vitality [13, 14, 15]. Germination generally begins after wheat seeds first absorb an amount of water equal to nearly 50% of their dry weight [16]. Germination is considered to be complete after the embryo and the roots have fully emerged from the seed [17]. In case the germinating seeds of a certain genotype dry up due to adverse environmental conditions, would it be possible for these seeds to germinate once again after they are re-exposed to water? It is indeed possible. Seeds of different genotypes differ from one another with respect to their ability to germinate at varying levels of water availability [16, 18]. In addition, the duration of contact with soil water during the first rain (or first water uptake) is also an important parameter for germination. The amount of water absorbed by the seed during germination, and the behavior of the seed during the first hours [19] after it begins to absorb water significantly affect a seed's germination properties [20].

Furthermore, extending the duration of contact with water not only allows the seed to absorb more water and to increase its rate of expansion, but it is also effective for ending the dormancy of the seeds. For this reason, seed varieties that demonstrate rapid intake of water and early germination may be more sensitive to “alatav.”

To date, numerous studies have been conducted on the water uptake, the imbibitions, the soaking, and the germination characteristics of cereals. However, there are only a limited number of studies evaluating the ability of seeds to germinate once again after they have remained dry for different periods of time following their initial uptake of water (in a manner that mimics the exposure of seeds to the environmental condition called “alatav”). For this reason, the researchers of the current study investigated the germination ratio of different seeds belonging to six genotypes from three different species of cereals following their first and second uptake of water.

Within the context of this study, the researchers allowed seeds of each genotype to first absorb water for 1 to 50 hours, and then dried these seeds for a period of three weeks. The researchers then attempted to germinate these seeds once again in order to determine the differences between the genotypes’ germination ratios following exposure to a dry period.

II. Materials And Methods

A total number of six genotypes of three cereal species were used in this study. The six genotypes were Gerek and Sultan genotype in Bread wheat, Kunduru and Dumlupinar genotype in durum wheat and Karma and Presto genotype in Triticale. All of genotypes are widely sown under rain-fed conditions in Turkey. Genotypes were provided by Eskisehir Anatolian Agriculture Research Institute (ATAEM) in Turkey. Kernel traits of the genotypes of three cereal species were quite different as shown in Table–1.

Table–1
The kernel characteristics of genotypes of three cereal species.

Cereals	Initial moisture (%)	1000 kernel weight (g)	Seed color §	Protein (%)	PSI (%)	M-SDS (ml)
Bread wheat (2n = 42)						
Gerek	10.35	35.47	W	12.09	70.89	32.16
Sultan	10.64	36.05	LW	10.22	75.22	33.64
Durum wheat (2n = 28)						
Kunduru	10.23	46.60	LR	15.21	43.70	12.63
Dumlupinar	10.49	54.52	R	13.92	51.55	27.29
Triticale (2n = 42)						
Karma	10.09	34.14	DR	10.80	63.29	27.44
Presto	10.32	35.11	DR	10.78	68.28	26.30

§ *W – white, R – red, LW – light white, LR – light red, DR – dark red*

The study was arranged in a split split plots in randomized complete blocks design (where species were main plots, genotypes were sub plots, and hours were sub-sub plots) with three replications in a dark room with air conditioning. In each replication, there were 50 groups of seeds for each genotype and each group had 50 seeds. 50 seeds of each group for the initial weight (IW) were weighed before imbibition. 50 seeds of each group were placed on four layers of filter paper placed in petri dishes with a diameter of 5 cm. The Petri dishes were watered with 6 ml of distilled water and covered by plastic paraffin. Then the dishes were incubated in dark room with air conditioning regulated to maintain a constant 25° ± 1°C for 50 hours [21, 22]. Once an hour, all groups were taken out from dark room and their 50 seeds were dried by paper towel and their final weights (FW) of 50 were determined. WU percentage was calculated by the formula showed below [22, 23].

$$WUj = \frac{(FWj - IWj)}{IWj} \times 100$$

Where; WU – water uptake (%), FW – final weight (g), IW – initial weight (g), j – trait per hour.

In order to have them completely dried, the weighed seeds were kept on a paper towel at 25°C (± 1°C) with 43% air humidity for 3 weeks. After 3 weeks, all groups were put on four layers of filter paper in petri dishes and watered and the petri dishes were again. They were covered by plastic paraffin and kept in the same room for 4 days under the conditions described above. At the end of 4 days, germination counts of groups were performed. The seeds that had coleoptile, radicle and seminal roots were counted as germinated (Fig–1:A).

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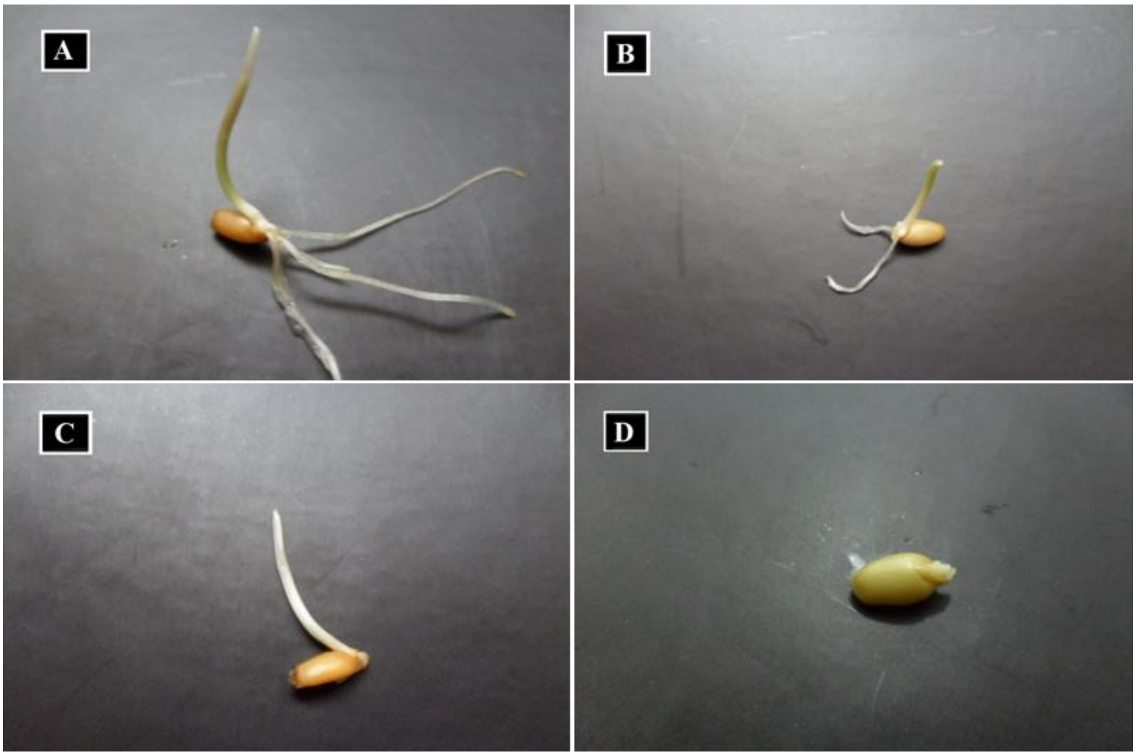

Fig–1: The pictures of germinated (A and B) and non-germinated (C and D) of some seeds.

In some seeds, the radicle has not observed on germination of second imbibition because it had emerged in the first imbibition and then died. Those seeds had only coleoptile and seminal roots, and so they were also counted as germinated (Fig–1:B). If the seeds did not have collectively coleoptiles and seminal roots (Fig–1:C) or no one (Fig–1:D), they were considered as non-germinated. In the cases where germination was observed, germination rate (GR) was calculated by following formula;

$$GRj = \frac{NGj}{50} \times 100$$

Where; GR – germination rate (%), NG – number of germinated seeds, 50 – number of total seeds.

In a randomized complete block factorial design arrangement with three genotypes, the effects of water uptake time (from 1 to 50 hours) after second imbibition on germination rate were investigated. The collected data were subjected to statistical analysis using MSTAT–C software. When the F–test indicated a statistical significance at $P < 0.01$ or $P < 0.05$ probability levels, mean comparisons were made by LSD.

III. Results

According to the variance analysis shown in Table–2, water uptake (WU) and germination rate (GR) were significantly affected by the cereal species (C), the imbibitions times (T), the C × T interaction and the genotype (G) × T interaction in cereal species ($P < 0.01$). The WU was significantly affected by G and C, while GR was not.

With a mean WU value of 105.2% at 50 hours, the triticale species had the highest WU value (Table–3). With respect to mean WU, triticale was followed by bread wheat (70%). It is interesting to note that although durum wheat had the lowest mean WU value (54.1%) among the three cereal species; it also had the highest GR value (47.3%). Bread wheat had the second highest GR value. Although triticale had the highest mean WU value, it also had the lowest mean GR value. No significant relationship was observed between the WU and GR values of the cereals.

As can be seen in Table–3, the Karma and Presto genotypes of the triticale species had the highest mean WU values among all of the genotypes (110.3% and 100.2%, respectively).

International Journal of Recent Development in Engineering and Technology
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However, while these genotypes had higher WU performances than the genotypes of other species, their mean GR values were not similarly higher. Although the Kunduru and Dumlupinar genotypes of durum wheat had the lowest mean WU values, they still had the highest mean GR values (47.5% and 47.2%, respectively).

It was interesting to note in the study results that the WU and GR values of all genotypes were inversely related ($r = -0.7545^*$). Moreover, this inverse relationship between WU and GR values was higher and more pronounced between the genotypes of the same species ($P < 0.01$).

Table–2:
Analysis of variance of water uptake (WU) and germination rate (GR) of seeds as affected by cereal species (C) and their genotypes (G) and imbibition times (T).

Source	DF Num	WU	GR
Replication	2	49.684	195.64
C	2	205474 **	7474 **
Error – 1	4	40.762	67.9
G [in C]	3	9904.3 **	1347.3
Error – 2	6	55.036	323.71 **
T	49	11837 **	27227 **
C × T	98	479.31 **	218.23 **
G × T [in C]	147	85.614 **	39.801 **
Error – 3	588	48.2	20.43
C. Total	899		

Table–3:
The mean water uptake (WU) and germination rate (GR) of three cereal species and their genotypes.

Variable		Water Uptake (%)	Germination Rate (%)
Cereal species			
	Triticale	105.2	37.4
	Bread wheat	70.0	41.3
	Durum wheat	54.1	47.3
	Mean	76.4	42.0
LSD $_{(0.05)}$		1.4	1.9
Genotype			
	Karma	110.3	36.1
	Presto	100.2	38.7
	Gerek	68.9	44.7
	Sultan	71.1	37.8
	Kunduru	62.6	47.5
	Dumlupinar	45.6	47.2
	Mean	76.5	42.0
LSD $_{(0.05)}$		2.0	2.6
CV $_{(\%)}$		9.1	10.7

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While bread wheat had the highest WU value in the first hour of imbibition, triticale had a higher WU value starting from the second hour, triticale's WU value increased rapidly, parallel to the imbibition time, and was the highest at 50 hours (Table–4). The WU value of durum wheat increased at a slower rate in comparison to the other two species. The triticale species reached a WU value equal to 50% of its dry weight in five hours. Triticale was followed by bread wheat, which reached a WU value equal to 50% of its dry weight in nine hours, while durum wheat reached a WU value equal to 50% of its dry weight in 16 hours.

The GR value of durum wheat decreased below 90% after the 10th hour of imbibition, and continued to decrease with each additional hour of imbibition until reaching 0% at the 40th hour.

The WU value at this imbibition time was 74% (Table–4; Fig–2). The GR value of bread wheat decreased below 90% at the 9th hour of imbibition, while that of triticale decreased below 90% at the 7th hour of imbibition. Bread wheat seeds stopped germinating after reaching a WU value of 88.2% in the 36th hour of imbibition, while triticale seeds stopped germinating after reaching a WU value of 135.2% in the 35th hour of imbibition. The increase in WU values was associated with a rapid decrease in GR values in all genotypes of bread wheat, durum wheat, and triticale. According to the correlation between GR values and WU values until the imbibition hour at which no germination was observed, the correlation values for bread wheat, durum wheat, and triticale were r = –0.8857**, r = –0.8694** and r = –0.9070**, respectively.

International Journal of Recent Development in Engineering and Technology
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Table–4:
The water uptake (WU) and germination rate (GR) of seeds of three cereal species from 1 hour to 50 hours.

	Water uptake (%)			Germination rate (%)		
Time (h)	Bread w.	Durum w.	Triticale	Bread w.	Durum w.	Triticale
1	6.5	3.2	5.9	99.3	100.0	100.0
2	18.2	11.0	21.7	99.0	99.7	100.0
3	25.5	16.1	37.0	96.0	99.7	95.7
4	28.8	21.5	42.7	94.7	100.0	97.7
5	36.3	25.6	51.6	94.7	98.7	96.7
6	38.3	26.6	58.7	93.3	96.7	94.0
7	42.7	30.3	60.9	91.7	95.3	92.0
8	44.6	33.1	68.4	93.0	95.7	87.3
9	50.5	36.9	72.2	91.3	94.0	86.0
10	52.6	39.8	75.4	88.7	90.3	87.7
11	52.1	37.9	79.0	88.3	88.0	82.3
12	52.6	38.0	81.6	86.0	84.3	81.0
13	58.1	44.2	87.4	82.7	81.3	81.0
14	58.6	45.2	80.1	81.0	81.3	79.0
15	60.8	47.3	93.2	82.0	78.7	74.0
16	61.1	50.4	96.6	76.0	78.3	71.0
17	62.4	49.9	95.0	71.7	79.7	65.7
18	63.6	48.2	100.5	68.0	76.7	57.0
19	63.9	50.1	91.7	63.7	71.3	52.3
20	66.1	52.6	96.5	61.0	72.7	46.0
21	66.2	52.5	102.0	54.7	70.3	41.3
22	67.3	54.7	101.1	49.7	73.0	39.0
23	69.5	57.6	104.2	48.0	67.0	30.3
24	70.8	57.9	110.7	38.3	61.3	26.7
25	74.3	56.4	109.9	35.0	57.0	25.7
26	72.0	57.2	112.4	30.7	50.3	23.7
27	72.7	58.9	112.2	30.0	45.3	17.0
28	79.2	63.1	114.7	19.0	38.3	13.0
29	77.1	60.2	118.1	15.3	31.3	8.0
30	80.5	61.7	120.2	12.0	29.7	7.3
31	81.1	64.0	128.7	8.7	22.0	4.7
32	84.7	63.7	128.8	9.7	19.3	3.0
33	81.2	60.4	134.7	6.3	13.3	1.7
34	89.5	66.3	134.7	2.7	10.3	0.7
35	83.6	66.6	135.2	0.7	6.0	0.3
36	88.2	68.2	129.7	0.7	4.7	-
37	87.2	69.5	132.1	-	2.0	-
38	88.0	66.6	133.4	-	1.0	-
39	86.4	71.4	135.3	-	1.3	-
40	92.8	74.0	141.0	-	0.3	-
41	94.5	70.4	142.0	-	-	-
42	93.0	77.1	138.9	-	-	-
43	96.1	77.3	143.2	-	-	-
44	96.5	69.6	141.6	-	-	-
45	95.7	71.4	143.8	-	-	-
46	97.4	73.5	146.1	-	-	-
47	97.4	71.0	141.2	-	-	-
48	97.4	78.8	141.7	-	-	-
49	99.2	78.5	146.0	-	-	-
50	98.3	77.8	141.8	-	-	-
mean	70.0	54.1	105.2	57.3¶	59.2¶	53.4¶
LSD $_{(0.05)}$		7.9			5.1	

¶ *The mean of germinated seeds per hour only*

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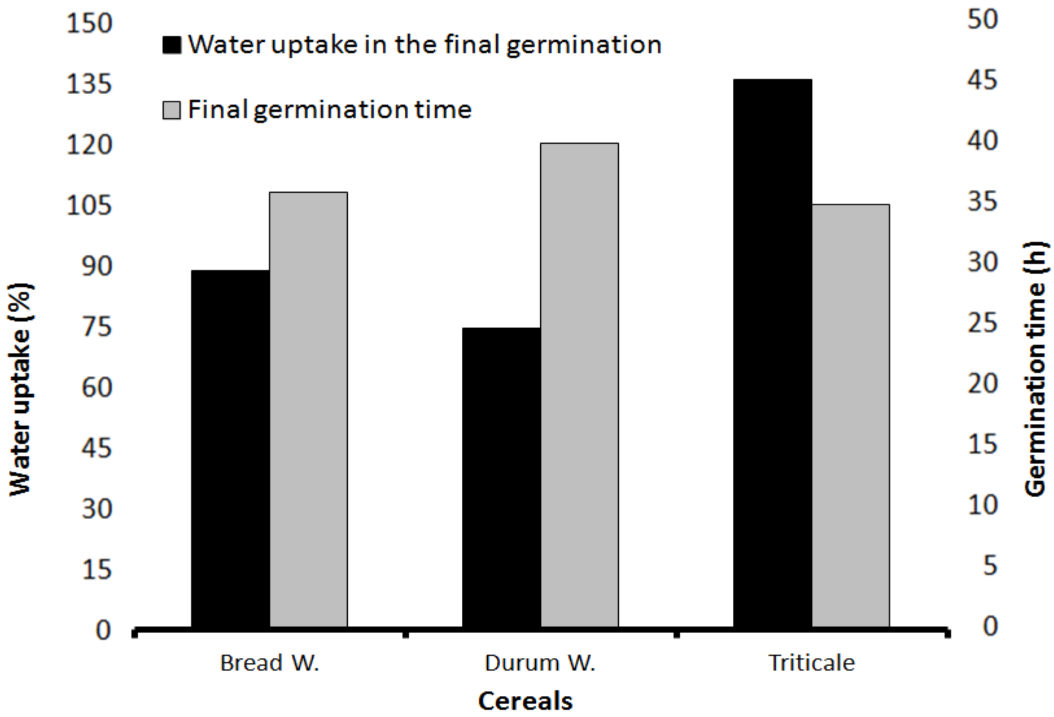

Fig–2: The final germination times of cereal species and their water uptakes (WU).

As can be seen in Table–5, the genotypes with the highest WU values were the Karma and Presto genotypes of triticale (110.3% and 100.2%, respectively). The WU of the Karma genotype reached a value greater than 50% of its dry weight at the 4th hour of imbibition, while Presto achieved the same WU value at the 4th hour of imbibition. These genotypes were followed by the Gerek and Sultan genotypes of bread wheat, whose WU reached values greater than 50% of their dry weight at the 8th and 9th hours of imbibition, respectively. In comparison to the other genotypes, the durum wheat genotypes required longer imbibition times to reach a WU value of 50%. The Kunduru and Dumlupinar genotypes of durum wheat were also different from one another in this respect: the Kunduru genotype seeds reached a WU value of 50% after the 12th hour of imbibition, while Kunduru genotype seeds reached the same value after the 26th hour of imbibition, thus demonstrating a significant difference between the two.

Dumlupinar was also the genotype that retained the ability to germinate for the longest period of time. Seeds of this genotype could still germinate (GR 0.7%) at the 40th hour of imbibition, when the WU value was 64.3%. However no germination was observed with this genotype past the 40th hour of imbibition. Also, the Kunduru genotype fully lost its ability to germinate three hours earlier than the Dumlupinar genotype. The Kunduru genotype had a GR value of 1.3% at the 37th hour of imbibition, at which time the WU value was 78.2%. In terms of the longest period for which the ability to germinate was preserved, the Kunduru genotype was followed by the Gerek genotype of bread wheat (89.2% WU at 36th hour) and the Presto genotype of triticale (136.8% WU at 35th hour). The Sultan and Karma genotypes did not germinate after the 33rd hour of imbibition (at WU value of 80.1% and 136.5%, respectively); they were thus the genotypes that lost the ability to germinate within the shortest imbibition period (Fig–3).

International Journal of Recent Development in Engineering and Technology
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Table–5
The water uptake (WU) and germination rate (GR) of genotypes of three cereal species from 1 hour to 50 hours.

	Water uptake (%)						Germination rate (%)					
	Bread w.		Durum w.		Triticale		Bread w.		Durum w.		Triticale	
Time (h)	GR	SL	KN	DM	KR	PR	GR	SL	KN	DM	KR	PR
1	6.4	6.7	4.2	2.1	5.5	6.3	100.0	98.7	100.0	100.0	100.0	100.0
2	18.0	18.4	12.8	9.1	21.3	22.1	100.0	98.0	100.0	99.3	100.0	99.3
3	26.4	24.5	17.7	14.5	36.4	37.6	98.0	94.0	99.3	100.0	96.0	95.3
4	29.4	28.2	25.0	18.0	43.7	41.7	97.3	92.0	100.0	100.0	97.3	98.0
5	38.6	33.9	30.8	20.5	54.9	48.3	96.0	93.3	98.0	99.3	96.7	96.7
6	39.6	37.1	32.7	20.4	69.0	48.5	94.7	92.0	95.3	98.0	94.7	93.3
7	43.9	41.6	36.5	24.2	66.3	55.6	92.7	90.7	94.7	96.0	91.3	92.7
8	43.1	46.1	38.9	27.4	76.3	60.4	94.0	92.0	94.7	96.7	85.3	89.3
9	51.4	49.6	44.5	29.2	77.8	66.5	92.7	90.0	93.3	94.7	80.7	91.3
10	50.5	54.6	46.7	32.8	82.5	68.2	88.7	88.7	88.0	92.7	84.7	90.7
11	52.4	51.7	43.6	32.2	87.4	70.6	90.7	86.0	89.3	86.7	80.0	84.7
12	53.1	52.2	43.4	32.6	96.7	66.4	89.3	82.7	88.0	80.7	76.0	86.0
13	57.5	58.8	51.5	36.9	97.7	77.2	86.7	78.7	80.7	82.0	76.7	85.3
14	56.3	60.9	52.3	38.2	90.8	69.4	87.3	74.7	80.0	82.7	74.7	83.3
15	56.5	65.0	57.3	37.2	110.6	75.7	90.7	73.3	77.3	80.0	71.3	76.7
16	54.0	68.2	59.4	41.4	111.9	81.4	85.3	66.7	78.0	78.7	64.0	78.0
17	60.2	64.7	60.4	39.4	112.1	77.9	82.7	60.7	82.0	77.3	64.0	67.3
18	61.8	65.4	56.8	39.5	114.5	86.6	78.0	58.0	78.0	75.3	54.7	59.3
19	61.6	66.2	59.7	40.5	95.6	87.9	72.0	55.3	72.7	70.0	50.0	54.7
20	62.8	69.3	61.7	43.5	101.0	92.0	72.0	50.0	73.3	72.0	46.7	45.3
21	63.5	68.8	59.5	45.6	111.3	92.7	64.0	45.3	74.7	66.0	40.0	42.7
22	63.9	70.7	64.4	45.0	102.8	99.3	59.3	40.0	74.7	71.3	36.7	41.3
23	68.0	71.0	66.7	48.5	109.5	99.0	55.3	40.7	70.0	64.0	29.3	31.3
24	68.3	73.3	68.3	47.6	117.6	103.7	40.7	36.0	64.7	58.0	26.0	27.3
25	73.8	74.8	64.8	48.1	119.7	100.1	38.0	32.0	58.7	55.3	20.0	31.3
26	67.8	76.1	65.1	49.3	117.8	107.0	36.0	25.3	49.3	51.3	19.3	28.0
27	69.9	75.6	67.0	50.8	118.8	105.5	37.3	22.7	46.0	44.7	14.7	19.3
28	76.0	82.5	72.0	54.3	123.4	106.0	27.3	10.7	37.3	39.3	12.0	14.0
29	75.1	79.0	70.5	49.9	123.7	112.6	22.7	8.0	33.3	29.3	4.7	11.3
30	79.0	81.9	68.6	54.7	125.6	114.8	16.0	8.0	32.7	26.7	4.0	10.7
31	78.2	84.0	74.6	53.4	133.9	123.6	14.0	3.3	21.3	22.7	4.7	4.7
32	82.8	86.7	72.1	55.2	133.8	123.7	16.0	3.3	20.7	18.0	2.7	3.3
33	82.3	80.1	69.1	51.7	136.5	132.9	11.3	1.3	9.3	17.3	1.3	2.0
34	88.4	90.6	77.4	55.2	139.3	130.1	5.3	-	8.0	12.7	-	1.3
35	80.9	86.3	75.7	57.5	133.5	136.8	1.3	-	6.7	5.3	-	0.7
36	89.2	87.2	80.8	55.6	122.4	137.0	1.3	-	2.7	6.7	-	-
37	86.5	87.9	78.2	60.8	128.9	135.3	-	-	1.3	2.7	-	-
38	87.3	88.6	74.3	59.0	136.4	130.3	-	-	-	2.0	-	-
39	81.9	90.9	80.4	62.4	136.3	134.4	-	-	-	2.7	-	-
40	89.6	95.9	83.6	64.3	145.4	136.6	-	-	-	0.7	-	-
41	94.7	94.2	82.5	58.3	148.2	135.9	-	-	-	-	-	-
42	91.7	94.4	90.2	64.0	146.0	131.7	-	-	-	-	-	-
43	98.3	94.0	88.2	66.5	151.2	135.3	-	-	-	-	-	-
44	95.4	97.6	76.8	62.4	139.9	143.4	-	-	-	-	-	-
45	96.1	95.3	80.8	62.0	139.2	148.4	-	-	-	-	-	-
46	100.8	94.0	83.0	64.0	142.2	150.1	-	-	-	-	-	-
47	96.6	98.2	80.2	61.8	142.7	139.6	-	-	-	-	-	-
48	97.8	97.0	94.1	63.4	145.7	137.6	-	-	-	-	-	-
49	100.7	97.7	92.8	64.2	145.6	146.4	-	-	-	-	-	-
50	97.2	99.3	92.0	63.7	144.2	139.4	-	-	-	-	-	-
mean	68.9	71.1	62.6	45.6	110.3	100.2	62.1[¶]	57.3[¶]	64.2[¶]	59.0[¶]	54.6[¶]	55.3[¶]
$LSD_{(0.05)}$								11.1			7.3	

[¶] *The mean of germinated seeds per hour only*

GR – Gerek; SL– Sultan; KN – Kunduru; DM – Dumlupinar; KR – Karma; PR – Presto

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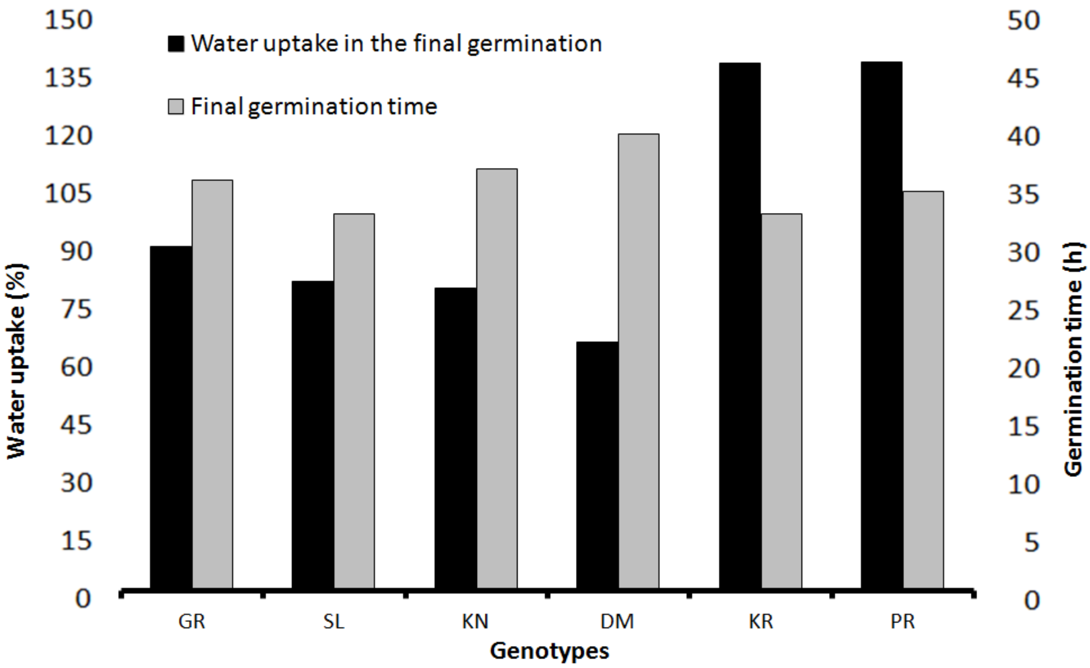

Fig–3: The final germination times of six genotypes of cereal species and their water uptakes (WU).

IV. Discussion

According to the study data, the WU and GR values were considerably affected by the species of cereal, the genotypes, the duration of first imbibition, and by the interaction of these parameters. While genotypes had a significant effect on WU values, their effect on GR was not significant. Numerous studies have demonstrated a close relationship between the WU values and the behavior of seeds during the first hours of imbibition [19, 20]. With regards to the WU values at the initial hours of imbibition, triticale was the cereal species that showed the fastest and highest level of water absorption, while durum wheat showed the slowest and lowest level of water absorption. Ashraf and Abu Shakra (1978) [16] previously reported that the absorption of an amount of water equal to 50% of a seed's dry weight had the effect of triggering germination in wheat seeds. According to the current study results, triticale seeds reached a WU value of 50% in five hours, while bread wheat and durum wheat seeds reached a WU value of 50% in nine and 16 hours, respectively.

With every hour of imbibition, the WU value of all species increased, while their GR values rapidly decreased. As such, the GR value dropped to 0% for durum wheat, bread wheat, and triticale following 40, 36, and 35 hours of imbibition, respectively. There were considerable differences between the different cereal species with respect to their WU values at the final germination time.

The water uptake of durum wheat at the final germination time was 16.1% less than that of bread wheat, and 45.3% less than that of triticale. These differences between the final germination times of the different species were more significant than the correlation calculated between the WU and GR values.

Many previous studies have reported significant differences in the water uptake levels of different species [14, 15, 16, 18]. The results of the current study were parallel to the findings of previous studies. Among the different genotypes, the Karma and Presto genotypes of triticale had the highest WU values, but also the lowest GR values. In contrast, the Kunduru and Dumlupinar genotypes of durum wheat had the lowest WU values and the highest GR values. The Dumlupinar genotype, in particular, retained its ability to germinate despite 40 hours of imbibition. With respect to the ability to germinate despite lengthy imbibition, the Dumlupinar genotype was followed by the Kunduru genotype with 37 hours; the Gerek genotype with 36 hours; the Presto genotype with 35 hours; and the Sultan and Karma genotypes with 33 hours.

In conclusion, the study results demonstrated that at any given time of imbibition, different cereal species displayed different WU and GR values. This difference was observed between different genotypes of the same species as well. The researchers concluded that these differences stemmed from genetic factors that determine the characteristics of wheat seeds.

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For instance, the seeds of the Kunduru and Dumlupinar genotypes of durum wheat, which had the slowest and lowest water intake, have a red and harder structure, a higher 1000 seed weight, and higher protein content than the seeds of the other genotypes (Table 1). Torada and Amano, Yucel et al. and Huang et al. [14, 15, 24]. reported that red colored seeds in wheat were more resistance than white colored seeds to early germination. The study data thus indicated that the genotypes of durum wheat are the cereals that are the least threatened by the risk of "alatav." Therefore, it might be useful and beneficial to conduct further studies regarding seed characteristics that lengthen the period of water intake, and that allow the seed's vitality to be preserved until the second uptake of water.

V. CONCLUSIONS

The results of this study are promising in that they show that possible solutions against the risk of alatav can be produced at the level of species and genotypes. In addition, it might be possible to obtain further significant results within the context of this study by including more genotypes and different types of soil conditions into the study design.

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