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GRAIN YIELD AND YIELD COMPONENTS AT DIFFERENT SOWING TIMES AND SOWING DEPTHS IN BARLEY (*Hordeum vulgare* L. CONV. *DISTICHON*) UNDER RAINFED CONDITIONS

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This experiment was conducted to determine the effects of different sowing dates (5th October, 20th October, 5th November, and 20th November) and sowing depths (2, 4, 6 and 8 cm) on yield and some yield characters in two rowed barley (cv. Tokak 157/37) under rainfed conditions. The field study was conducted in Kirsehir ecological condition during 2014-15 and 2015-16 winter growing seasons. Grain yield and important yield traits such as plant height, spike length, number of fertile spike per square meter, number of grain per spike and grain weight per spike were determined. Sowing dates and depths influenced significantly the grain yield and yield components in two consecutive years. Most of the yield components were adversely affected by deeper sowing depths and delayed sowing dates. Based on two-year average, the highest grain yield was recorded with 2733 kg ha^{-1} at 20th October sowing date and 4 cm depth; in contrast the lowest grain yield was 513 kg ha^{-1} by the 20th November and 8 cm depth.
Keywords: Cereals, *Hordeum vulgare,* crop production, dryland, arid agriculture, seedling emergence, grain yield.

INTRODUCTION

Cereals are the most important crop in Kirsehir ecologic conditions and barley is the second most important cereal in the region (Anonymous, 2017a). Barley is generally cultivated in the region during the late-September to the beginning of November. Even in some years, sowing time for barley is too early to encounter dry seed bed or little rainfalls. In contrast, delayed sowing time is come up against too early snows or cold days. Therefore, sowing date is most important factor to have high yield in cereals (Easson and Saunders, 1986; Conry, 1995). Generally, to minimize the risk of germination failure, sowing date in dryland regions is often delayed until an effective rainfall (over 25 mm) (van Keulen and Seligman, 1987; Russell, 1990).

It is important to have higher seed germination and seedling survival under suitable seedbed conditions for high yields (Conry, 1998a). Therefore, sowing time and depth are the most important characters for having suitable seedbeds to have successful cereal establishment with high yield (Perry, 1984). In terrestrial regions such as Kirsehir, soil moisture is generally in the upper layer of the soil at the optimum sowing time. Therefore, the sowing time can be delayed until suitable precipitation. Barley stands may be poorly established, resulting in low biomass. Mahdi *et al.* (1998) reported in wheat that delaying sowing beyond the optimum time can also lead to reduction in biomass. Alam *et al.* (2005) noted that late sown barley exposed to low temperature at the vegetative stage decreased the physiological processes in plants such as seedling growth and water uptake. Another major constraint to seed germination and seedling growth is incorrect sowing depth. In the region, varying sowing depths are practiced by the farmers. Some farmers sowed barley deeply as in case of wheat which results in poor seedling establishment. Barley may be more sensitive for deeper sowing than wheat genotype; because most barley varieties that are commonly grown in the region have shorter coleoptile lengths than wheat (Kaydan and Yagmur, 2005).

This study planned in rainfed conditions was aimed to determine the effects of sowing depths and dates on grain yield and yield traits in barley.

MATERIALS AND METHODS

This current field experiments were conducted during the 2014-2015 and 2015-2016 winter growing seasons in Kirsehir Province (39° 9′ N, 34° 10′ E and 1107 m above sea level). Tokak 157/37 two rowed barley cultivar was used as a test material.

The monthly rainfall, average temperature data for 2014-15, 2015-16 and long-term (1929-2017) averages are presented in Table 1. Kirsehir has a severely cold and snowy winter, relatively cool spring with rainy and dry summer. Rainfall is extremely variable, from season to season and within year. In the experimental years, i.e., 2014-15 and 2015-16 winter growing seasons, total rainfall was higher than those of the long-term average for the region. Moreover, total rainfall was higher in 2014-15 (590 mm) growing season than in 2015-16 (390.2 mm) (Anonymous, 2017b)

Soil analysis shows that the soil of experimental site had a sandy-clay-loamy texture with low organic matter (1.39%) and low nitrogen (0.070%) content, high potassium (63.78 ppm) and lime (21.8%) content, low phosphorus (0.19%) content and slight alkalinity (pH:7.59) (Kacar, 1995).

The research was conducted in a split plot design with four sowing times and four sowing depths with three replications. Each plot planned to contain 3 rows. Row lenght was 1 m and spaced 0.20 cm apart. Seeds were establishment at 2 cm of depth (1-2 cm), 4cm (3-4 cm), 6 cm (5-6 cm), or 8 cm (7-8 cm) and spaced approximately 1 cm apart along each row (500 seeds m^{-2}). Sowing dates were arranged as close as possible to 15-day intervals 5th October, 20th October, 5th November, and 20th November.

Fertilizers were applied in equal amounts to all plots. All plots were fertilized at sowing with 150 kg diammonium phosphate ha^{-1}. Moreover, 200 kg ammonium sulphate ha^{-1} was applied as a top dressing before ear emergence. Weeds were controlled with hand weeding as needed. No pest and disease issues were faced during the study.

Ten plants were selected at harvest randomly from the central one row. The grain yield and yield traits recorded for each plot were (i) plant height (cm), (ii) spike height (cm), (iii) number of grain per spike, (iv) grain weight per spike (g), (v) fertile spike per square meter, and (vi) grain yield (kg ha^{-1}). Grain yield (14.0% moisture basis) was recorded at maturity by harvesting the center one row of each plot for grain yield determination in July 2015 and 2016.

Variance analysis was performed using with the MSTAT-C statistical package. Results for each year were analyzed separately because rainfall differed between the two seasons and were presented by individual year. The data were then combined over years and presented as 2-year mean values. Mean of values were compared at $p<0.05$ level of probability using Duncan's multiple range test.

RESULTS AND DISCUSSION

The number of fertile spikes per unit area is an important character that was mostly influenced with sowing time and sowing depth in two seasons (Table 2). Among the sowing times examined in the current study, 5th October and 20th October sowing times produced the greatest number of fertile spikes (m^{-2}) and 20th Nowember the fewest in two years average. The delayed sowing times mostly reduced number of fertile spikes per unit area and the lowest fertile spikes were obtained in the last sowing time i.e. 20th November. Number of fertile spikes were recorded to increase with sowing depths up to 4 cm depth. Then, as the depth of sowing increased than 4 cm, a decrease was observed in the number of fertile spikes (m^{-2}). Interactive effect of sowing depths and dates affected the number of fertile spike in two season and two years average. The early sowing times with the shallower sowing depth had low number of fertile spike (m^{-2}) in comparison to the early sowing with the 4 cm sowing depth (Table 2). This was because of low rainfall at the early sowing time with the 2 cm depth, which negatively affected seedling number and resulted in low fertile spike per square meter. Shallower seedings may be due to placing seeds in soil that is very dry and results in poor or no germination in early dates. In contrast, fertile spike (m^{-2}) were higher in 2 cm sowing depth at the delayed sowing times in compared to other sowing depths.

Spikes per unit area was the most character for the grain yield in the dry areas as the grain yields were reduced up to 70% with late sowing while tiller number also tended to decline (Photiades and Hadjichristodoulou, 1984); however, high number of spikes per unit area were obtained from early sowing times than delayed sowing dates (Hadjichristodoulou

Table 1. Climate data for Kirsehir Province in 2014-15, 2015-16 and long-term (LTA) averages (1929-2017).

	Temperature (°C)			Rainfall (mm)		
Months	**LTA**	**2014-15**	**2015-16**	**LTA**	**2014-15**	**2015-16**
August	22.9	25.8	25.9	4.9	17.0	11.8
September	18.2	19.6	23.8	11.6	29.8	1.0
October	12.3	13.5	14.6	27.8	37.2	30.8
November	6.2	6.7	8.4	36.4	28.4	8.8
December	1.9	6.0	-1.2	47.0	28.6	10.2
January	-0.1	1.3	0.0	46.2	35.2	72.1
February	1.3	3.4	6.2	35.2	38.3	36.4
March	5.3	6.9	7.2	35.2	89.0	39.2
April	10.7	8.8	14.1	43.7	26.8	23.8
May	15.4	16.4	15.1	44.3	54.8	95.8
June	19.6	18.9	21.3	36.8	161.4	16.1
July	23.1	25.7	24.9	6.8	3.0	1.0
Average Temp.	11.4	12.7	13.3			
Total Rainfall				375.9	590.2	390.2

et al., 1977). Deeper sowing depth negatively affected the number of fertile spike per unit area because all germinated seeds did not establish seedling stand. Kaydan and Yagmur (2005) reported that barley may be more sensitive to deep sowing than wheat genotypes; because most of the barley cultivars have shorter coleoptile lengths compared to wheat cultivars. Yagmur and Kaydan (2009) reported that fertile spikes were low as compared to number of seedlings among wheat varieties with shorter coleoptile at deep sowing depth. The seedlings with thinner shoots were injured by winter stress.

Sowing depths and times had significant effect on plant height in two consecutive years (Table 2). Moreover, the average plant height was higher in first growing season than the second cropping season due to higher rainfall (Table 1). The first and second sowing times had similar plant height in 2014-15 and 2015-16. Early sowing increased plant height that was attributed to longer vegetative growth duration. In contrast, the delayed sowing significantly reduced plant height compared to early sowing times in the both seasons. Photiades and Hadjichristodoulou (1984) reported that early sowing increased plant height. Ozturk *et al.* (2006) also reported similar results in wheat.

Among the sowing depths, 2 and 4 cm produced the greatest plant height in 2014-15 which had high rainfall. In contrast, only 4 cm depth had the longest plant height during 2015-16. Although, longer plants were obtained in depth of 4 cm, and shallower and deeper sowing depths had comparatively shorter plant height. The interaction of sowing depth and dates also had significant effect on plant height determined in both years. Therefore, the longest plant height (69.0 cm) was obtained from the sowing depth of 4 cm and 20th October sowing date based on two year means (Table 2).

Data analysis showed that sowing times and sowing depths positively affected spike length and number of grains per spike (Table 3). Similar to plant height, the first year of

Table 2. Number of fertile spikes (m^{-2}) and plant height (cm) at various sowing times and depths in barley.

		Number fertile spike (m^{-2})			Plant height (cm)		
Sowing Times		**2014-15**	**2015-16**	**Average**	**2014-15**	**2015-16**	**Average**
5th October		327.3a***	246.3ab	286.8a	63.6a	59.8a	61.7a
20th October		315.0a	250.9a	282.9a	64.7a	61.6a	63.1a
5th November		263.3b	221.2b	242.2b	59.6b	55.2b	57.4b
20th Nowember		198.6c	172.9c	185.5c	55.5c	51.5c	53.3c
F value		131.9**	154.0**	257.3**	59.5**	33.3**	82.9**
Sowing Depths							
2 cm		333.6b	270.5b	302.1b	64.7a	61.5b	63.1b
4 cm		370.6a	307.8a	338.2a	67.6a	64.9a	66.2a
6 cm		267.8c	230.1c	248.4c	60.6b	56.8c	58.7c
8 cm		132.6d	83.3d	107.9d	50.3c	45.0d	47.6d
F value		679.9**	154.0**	1068.4**	135.06**	169.4**	303.8**
Sowing time x Sowing depth							
5th October	2cm	376.6b	235.3de	306.0de	65.0cd	62.0cde	63.50c
	4cm	444.0a	380.6a	412.3a	71.0a	64.7a-d	67.85 ab
	6cm	320.0de	256.0cd	288.0ef	67.0abc	64.7a-d	65.85 bc
	8cm	168.6gh	113.3g	140.9i	51.3g	48.0fg	49.65 fg
20th October	2cm	369.3b	334.0b	351.65c	66.0bcd	64.3bcd	65.15 bc
	4cm	440.0a	341.0b	390.5b	69.0abc	69.0a	69.0 a
	6cm	304.0e	255.3cd	279.65f	66.6f	66.7ab	66.35 abc
	8cm	146.6h	73.3h	109.95j	56.5bcd	46.6gh	51.55 ef
5th November	2cm	333.3cd	285.0c	309.15d	66.0abc	61.3de	63.65 c
	4cm	350.0bc	286.0c	318.0d	68.3abc	66.0abc	67.15 ab
	6cm	261.6f	240.6de	251.1g	57.6ef	51.3f	54.45 e
	8cm	108.3ı	73.3e	90.8j	46.6h	42.3h	44.45 h
20th November	2cm	255.0f	228.6f	241.3g	62.0de	58.3e	60.15 d
	4cm	248.3f	221.7e	235.0g	61.7de	59.0e	60.85 d
	6cm	184.6g	168.3f	176.3h	51.0gh	44.6gh	47.8.3 g
	8cm	106.6i	73.3h	89.95j	46.7h	43.0h	44.85 h
F value		12.8**	15.7**	24.2**	5.92**	10.5**	14.06**
Years		276.1a	222.5b		60.8a	57.0b	
F value		177.89**			160.4**		

*** Duncan Multiple Range test (P<0.05). Ns: Non significant, ** P<0.01, * P<0.05

experiment was more favorable for spike length in barley. Therefore, there was large spike length in sowing time and depth during 2014-15. In both seasons, high reduction in spike length was recorded in plots which were sown deep and late. The interaction between sowing depth and dates on spike lengths was significant during two seasons. Therefore, the longest spike height with 6.54 cm was obtained from the sowing depth of 4 cm at the second sowing time (Table 3). In contrast, the mean shortest spike length (3.91 cm) was obtained from the deepest sowing depth with the last sowing date (20th November).

The correlation and path coefficient analyses have indicated that number of fertile spike per unit area are the major contributors to grain yield (Garcia del Moral *et al.*, 1991; Sinebo, 2002). Furthermore, grain yield is highly influenced by number of grains per spike (Sinebo, 2002). The most important yield character, number of grains per spike, was significantly affected by sowing dates and depths in 2014-15 and 2015-16 (Table 3). The delayed sowing reduced number of grains per spike. The lowest number of grains per spike were obtained with the delayed sowing in this study. Ozturk *et al.* (2006) reported that delayed sowing reduced grain number per spike in wheat. Another major effect on number of grains per spike was sowing depth that negatively affected number of grains, but the highest number of grains were obtained in the 4 cm depth of sowing in 2014-15 and 2015-16. Moreover, in two seasons, the lowest grain number per spike was obtained at the deepest sowing but varied with sowing times. Deeper sowing in barley delayed seedling emergence and lowered seedling growth; therefore, reduction in plant growth at the deepest sowing resulted in low number of grains per spike.

Based on the interaction effect, the highest average number of grain per spike was obtained with 16.80 and 16.65 from the first and second sowing dates, respectively, at 4 cm sowing depth.

Table 3. Spike length (cm) and number of grains (spike^{-1}) at various sowing times and depths in barley.

		Spike length (cm)			Number of grains (spike^{-1})		
Sowing Times		**2014-15**	**2015-16**	**Average**	**2014-15**	**2015-16**	**Average**
5th October		6.25a***	5.55a	5.90ab	15.5a	13.9a	14.75a
20th October		6.36a	5.75a	6.06a	15.4a	13.5a	14.45a
5th November		5.83b	5.50a	5.66b	13.6b	12.1b	12.88b
20th Nowember		5.12c	4.65b	4.88c	12.2c	10.8c	11.48c
F value		85.4**	28.73**	90.21**	87.3**	26.1**	85.20**
Sowing Depths							
2 cm		6.27a	5.72ab	6.00a	14.3b	13.4ab	13.85b
4 cm		6.38a	5.95a	6.17a	16.4a	13.9a	15.15a
6 cm		5.84b	5.29b	5.56b	14.8b	12.9b	13.57b
8 cm		5.08c	4.48c	4.78c	11.6c	10.3c	10.95c
F value		80.20**	41.30**	105.50**	66.8**	60.9**	124.30**
Sowing time x Sowing depth							
5th October	2cm	6.50abc	5.83	6.16ab	15.50bc	15.2a	15.35b
	4cm	6.80ab	5.93	6.36ab	18.30a	15.3a	16.80a
	6cm	6.30cd	5.66	5.98bcd	16.30b	14.3abc	15.30b
	8cm	5.43g	4.76	5.10f	12.00fgh	11.0fgh	11.50f
20th October	2cm	6.36bcd	5.76	6.06bcd	15.00bcd	13.7bcd	14.35bc
	4cm	6.83a	6.26	6.54a	18.30a	15.0ab	16.65a
	6cm	6.40a-d	5.86	6.13abc	16.00bc	14.0a-d	15.00b
	8cm	5.86fg	5.13	5.50f	12.30fg	11.3fg	11.80ef
5th November	2cm	6.23c-f	5.86	6.05bcd	13.30f	12.6d	12.95d
	4cm	6.40a-d	6.30	6.35ab	15.30bc	13.6cd	14.45bc
	6cm	5.83fg	5.46	5.65d	14.60cd	12.6d	13.60cd
	8cm	4.86h	4.36	4.61g	11.30gh	9.7hi	10.50g
20th November	2cm	6.00df	5.43	5.71cd	13.50df	12.1f	12.80de
	4cm	5.50g	5.33	5.41f	13.60df	11.8f	12.70de
	6cm	4.83h	4.16	4.50g	10.56h	10.0ghi	10.28g
	8cm	4.16i	3.66	3.91h	11.00gh	9.3i	10.16g
F value		4.10**	2.17^{Ns}	5.13**	5.61**	2.31*	7.25**
Years		5.89a	5.36b		14.20a	12.6b	
F value		233.06**			910.79**		

*** Duncan Multiple Range test (P<0.05). Ns: Non significant, ** P<0.01, * P<0.05

Table 4. Grain weight (g spike^{-1}) and yield (kg da^{-1}) at various sowing times and depths in barley.

		Grain weight (g spike^{-1})			Grain yield (kg ha^{-1})		
Sowing Times		**2014-15**	**2015-16**	**Average**	**2014-15**	**2015-16**	**Average**
5th October		0.73b***	0.69b	0.71b	1708b	1458c	1583b
20th October		0.84a	0.74a	0.79a	2036a	1791a	1913a
5th November		0.70b	0.70ab	0.70b	1670b	1606b	1638b
20th Nowember		0.56c	0.62c	0.58c	1254c	1188d	1221c
F value		25.40**	15.91**	40.07**	27.4**	96.12**	73.43**
Sowing Depths							
2 cm		0.63b	0.67b	0.65b	1689c	1560c	1630c
4 cm		0.80a	0.75a	0.77a	2303a	2124a	2213a
6 cm		0.77ab	0.74ab	0.75a	1875b	1177b	1807b
8 cm		0.65b	0.57c	0.61b	803d	625d	804d
F value		5.89**	25.70**	17.07**	450.1**	400.48**	847.0**
Sowing time x Sowing depth							
5th October	2cm	0.62	0.63e-i	0.62	1616e	1217 e	1416 g
	4cm	0.86	0.73b-e	0.79	2266bc	2033 bc	2149 cd
	6cm	0.88	0.83ab	0.85	2116c	1983 bc	2049 d
	8cm	0.58	0.55hi	0.56	833g	600 fg	716 i
20th October	2cm	0.73	0.70c-g	0.72	1693e	1660 d	1676 f
	4cm	0.92	0.88a	0.90	2906a	2561 a	2733 a
	6cm	0.86	0.80abc	0.83	2413b	2226 b	2319 b
	8cm	0.86	0.60ghi	0.73	1130f	716 fg	923 h
5th November	2cm	0.69	0.69c-g	0.69	1740de	1630 d	1685 f
	4cm	0.76	0.76bcd	0.76	2310bc	2240 b	2275 bc
	6cm	0.71	0.71c-f	0.71	1926d	1850 cd	1888 e
	8cm	0.63	0.63e-i	0.63	703gh	703 fg	703 i
20th November	2cm	0.46	0.66d-g	0.56	1706e	1763 cd	1733 f
	4cm	0.64	0.62e-i	0.63	1730de	1663 d	1696 f
	6cm	0.59	0.60f-i	0.59	1033f	856 f	942 h
	8cm	0.53	0.51ı	0.52	546h	480 g	513 j
F value		0.91^{Ns}	3.62**	1.87^{Ns}	22.30**	26.30**	46.80**
Years		0.71	0.68		1667.00a	1511.00b	
F value		4.67^{Ns}			994.62**		

*** Duncan Multiple Range test ($P<0.05$). Ns: Non significant, ** $P<0.01$, * $P<0.05$

Grain weight per spike changed according to sowing depth and times in both of seasons (Table 4). The delayed sowing times reduced grain weight per spike. Although, the lowest grain weight per spike was obtained at the last sowing time, whereas, higher grain weight per spike was obtained at the second sowing time in both years. There was a significant reduction in grain weight per spike at the 8 cm sowing depth in comparison to shallower sowing depths in both years (Table 4). Sowing depth and times interaction effects on grain yield per spike were significant. Therefore, the highest grain yield per spike with 0.92 g was obtained from the sowing depth of 4 cm at the first sowing date (Table 4). In contrast, the lowest grain weight per spike (0.53 g) was obtained from the deepest sowing with the last sowing date.

The results showed that early and late sowing had marked influence on grain yield in barley. There was essentially no seedling emergence was observed in the first sowing time till optimum rainfall. Generally, the optimum rainfall for germination in the region occurs in mid-October. It was found that sowing time is dependent on an optimum rainfall pattern (Photiades and Hadjichristodoulou, 1984). Väisänen *et al.* (2003) concluded that no more than a week or ten days delay from the earliest suitable sowing date can be recommended, if the soil moisture conditions are not suitable.

The delayed sowing had low grain yield than early sowing. Similarly, low grain yield due to delayed sowing was also reported by Noworolnik and Leszczynska (1997). Moreover, Conry (1998b) reported that sowing dates had a significant effect on grain yield and generally the early-sown spring malting barley gave the higher grain yield. Difference in grain yield of various sowing times was attributed to significant reduction of fertile spike per m^2, number of grains per spike, grain weight per spike (Tables 2, 3, 4). Samarah and Al-Issa (2006) reported that number of spikes per unit area, thousand grain weight and grain yield were higher in early sown crop compared to late sown. Moreover, Al-Rjoub (1984) reported

that early sown barley in comparison to late sown barley increased the total number of fertile spike, grain weight per spike, plant height, and number of grains per spike.
Generally optimum sowing depth is also an important factor in cereals management practices (Kirby, 1993; Mahdi *et al*., 1998). In both seasons, deep sowing reduced grain yield and the highest grain yield was obtained at the depth of 4 cm and it was followed by 2 cm, 6 cm and 8 cm depth. Deep sowing compared to 2 cm, delayed seedling emergence, causing weak seedlings stand and lowered seedling number, which ultimately resulted in a reduction in grain yield. Therefore, the results showed that the lowest grain yield was recorded at the deepest sowing depth. The present study showed that the reduction in grain yield depended on sowing depth and attributed to a significant reduction of fertile spike per unit area. Deeper (8 cm) sown barley than that of 4 cm highly reduced fertile spike at the delayed sowing dates. Sowing depth at the 4 cm increased some grain yield components such as stem height, spike length, number of grain per spike and grain weight per spike, whereas, grain yield; however, grain yield was low at the 8 cm sowing depth due to low number of fertile spikes. Early sowing at appropriate depth in barley under low or no rainfall is an important first step towards achieving vigorous and healthy seedlings. Early and shallow sowing reduced seedlings number and eventually the spike per unit area. Seeds in shallow seed beds were germinated with low rainfall, but the humidity in shallow seed beds was insufficient for survival of germinated seeds. Therefore, germinated seeds may remain dry till optimum rainfall. In contrast, in the delayed sowing, the 2 cm sowing depth was optimum sowing depth for achieving higher grain yield. In addition, in the rainy season or a little less rainy years, the shallow sowing became more efficient as the sowing time was delayed. Similar results in wheat were reported by Lafond *et al.* (2005) who observed better plant stands with shallow planting combined with delayed sowing. Moreover, weak seedlings from the deepest sowing was affected negatively with winter hardiness. Lafond *et al*. (2005) reported that the quicker emergence in wheat provides an advantage in seedling development and plant maturity. Moreover, most of the yield traits were adversely affected by deep sowing.

Conclusion: It is concluded that sowing time and depth are two most important factors for getting high grain yield in barley in dry environment. The results showed that early and late sowing had marked influence on grain yield in barley. There was essentially no seedling emergence was observed in the first sowing time till optimum rainfall. Therefore, in the region, optimum sowing time is during mid-October to late-October, which would have more advantageous than other sowing times that were used in this study. In addition the present study showed that the reduction in grain yield depended on sowing depth and attributed to a significant reduction of fertile spike per unit area. Moreover, the optimum sowing depth for barley in delayed sowing times may not be more than 2 cm; whereas, optimum sowing depth in the early sowing can be 6 cm without any risk to grain yield.

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