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Determination of Yield and Yield Characteristics of Some Barley (*Hordeum vulgare* L.) Genotypes Under Supplemental Irrigation Conditions in Van

Mahmut ACIKGOZ[1], Sana SALIH[1], Burak OZDEMIR[1], Erol ORAL[2*]

[1]*Van Yüzüncü Yıl University, Institute of Science, Department of Field Crops /Van, Turkey*
[2]*Van Yüzüncü Yıl University, Faculty of Agriculture, Department of Field Crops/Van, Turkey*
**Corresponding author: sanajsalih@gmail.com*

RESEARCH ARTICLE

Abstract

This research was carried out to investigate the adaptability abilities of some barley varieties in Van ecological conditions in the winter growing season of 2020-2021. Sixteen genotypes were grown according to randomized block design with three replications. The quantity of supplemental irrigation was equivalent to a total precipitation of 114 mm. According to the results obtained, the number of days to spike was 167.67-175.66 days, plant height 63.37-91.85 cm, number of spikes per square meter 403.67-619.67, lodging 0-10%, chlorophyll 45.34- 53.09 SPAD units, maturity period 36.0-36.7 days, canopy temperature 30.0-30.4 °C, spike length 7.30-9.96 cm, number of spikelets per spike 33.8-21.7, number of fertile spikelets 7.13-15.73, thousand grain weight 36.67-45.83 g, hectolitre weight 62.30 – 66.10 kg/hl, biological yield 20.36-20.45 t/ha, and grain yield 3.08–6.98 t/ha. The highest grain yield was obtained from two row barley varieties; Calabey, Akar, Tosunpasa and Asil. The highest biological yield was measured in Anka-11 and Aydanhanim cultivars.

Keywords: barley varieties, irrigation conditions, yield and yield components.

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INTRODUCTION

Barley is an essential component in livestock concentrated feed, it is used for malt production, and in human nutrition. Turkey is one of the important gene centres of barley (*Hordeum vulgare* L.), and among the top five barley producers in the world. According to the Food and Agriculture Organization, the worldwide cultivation area of barley was 2.8 million hectares in 2019, the production amount was more than 7.7 million tons with a yield average of 2.7 t/ha (FAO, 2021). In Turkey, it has the second place, after wheat, in the amount of crops cultivation area and production. Among Turkey's province, Van has an important place in terms of livestock production, and using barley as a raw material in producing concentrate feed is very common (Budag, 2011). 70-80% of the harvested barley were grown in arid and semi-arid areas (Kendal et al., 2010; Kendal, 2016). The total production of barley in Van was 13.387 tons from 754 hectares with an average of yield 1.85 t/ha (Altuner et al., 2019). However, feed producers in Van get the majority of the raw material (85%) from neighbouring provinces (Budag, 2011). Therefore, increasing barley production will make a significant contribution to the economy of the province. Various studies have been carried out for increasing yield and their results were promising. This resulted in cultivating new high yielding varieties, adopting winter sowing, and irrigation. Different cultivars and breeding lines were evaluated in different climatic and ecological conditions to understand their tolerance to drought. Genotypes

performance and adaptation ability were determined through studying tolerance, stress susceptibility index, stress tolerance index, mean productivity, and geometric mean productivity (Szira, 2008; Akcura and Ceri, 2011; Najarchi, 2017).

The access of existing feed factories to cheaper raw materials will be provided by these and similar studies. The availability of these studies under Van region growing conditions is thought to have a unique value in terms of detecting varieties with high yield potential and expanding barley farming in the lands opened for irrigation (Altuner, 2019). The value of the current study is through determining barley varieties suitable for Van area in irrigated land conditions which provides producer with scientific and practical studies. Thus, growing suitable certified varieties increase and raw material needed by the industry might be supplied inexpensively. For this purpose, yield and quality traits of 16 barley genotypes were evaluated under Van ecological conditions with supplemental irrigation to determine their adaptability in dry conditions.

MATERIALS AND METHODS

Plant materials and field experiments

The field experiment was conducted during the winter wheat growing season in 2020-21 at the experimental field in Van Yüzüncü Yıl University, Faculty of Agriculture, Field crops department research field to evaluate barley performance under Van growing conditions. The climate data of the trial site are given in Table 1. The experiment included 16 barley varieties; Avci 2002 and Olgun (6-row), Akar, Anka-06, Anka-08, Anka-09, Anka-10, Anka-11, Asil, Aydanhanim, Bozlak, Burakbey, Calabey, Larende, Tarm-92, and Tosunpasa (2-row). The experiment was randomized complete block design with three replications, the experimental unit consisted 48 parcels. Plots of each genotype were sown on 22 Dec 2020, 450 seeds m^{-2} were planted in 5 rows x 2 m length x 0.17 m space between rows.

Fertilization and irrigation

Based on the soil analysis (Table 2) and the crop requirements, each parcel was fertilized with 80 kg/ha P_2O_5 and 100 kg/ ha N. Supplemental irrigation was applied twice at botting stage and heading stage. At each irrigation, 1500 l/hour of water was applied to the parcels using semi mobile PE sprinkler system.

Agronomic measurements

In the experiment, the plants were monitored on a twice weekly basis to record the parameters. Number of days to start heading (NDH) was recorded visually when spikes exertion from 50% of main spikes. Plant height (PH) was measured at full stature from the soil surface to the tip of the spike without the awns. At heading stage number of spikes per square meter (NSSM), lodging rate (LR), chlorophyll concentration (CL), and plant temperature (PT) were recorded. Physiological maturity (MT) was determined visually from heading until 90% of the chlorophyll deplete from the peduncle. Then, 5 plants were harvested randomly from each plot and their main stem was used for measuring: spike length (SL), number of spikelets per spike (NSPS), number of fertile spikelets per spike (NFSS). Finally, all parcels were harvested after eliminating the plot edges and 1000 grain weight (TGW), hectolitre weight (HW), biological yield (BY), grain yield (GY), and harvest index (HI) were measured. Statistical analyses were performed using 6.303 CoHort Software. The difference between mean values was determined according to the LSD multiple comparison method.

Table 1. Climate data of the experiment

Months	Rain (mm)		Temperature (^{0}C)		Relative Humidity (%)	
	2020-2021	LYA	2020-2021	LYA	2020-2021	LYA
September	5.6	13.7	20.1	17.3	41.3	-
October	1.8	48.7	13.3	10.5	53.0	58.9
November	12.8	51.5	6.7	4.7	65.4	67.1
December	27.7	42.0	1.4	-0.7	71.5	72.5
January	11.7	46.2	-0.7	-1.8	67.2	70.8
February	18.0	82.0	0.8	-0.6	73.3	71.8
March	53.6	40.8	3.7	3.8	66.9	66.5
April	7.1	51.5	11.7	9.9	48.8	52.7
May	22.7	35.0	16.7	14.6	46.4	53.6
June	-	16.0	21.6	19.2	32.0	43.3
Total	161	419.1	-	-	-	-
Means			**9.53**	**8.99**	**56.58**	**60.22**

*LYA: Long Years Average

Table 2. Soil analysis of the experiment site

pH	Texture	CaCO3 (%)	OM %	EC dSm^{-1}	P %	K ppm
7.80	loam-clay	3.35	0.98	2.34	5.25	217

RESULTS AND DISCUSSIONS

Days to head determined as the time from the emergence of the varieties to the beginning of the head. The number of days to heading in the experiment varied between 168.67 and 175.66 days. The longest heading period was found in Olgun and Avci-2000 cultivars with 175.33 and 175.66 days, whereas Anka-06 had the shortest number of days to heading with 167.33 days (Table 3). Values form current study was lowest compare to what Kaydan and Yagmur (2007) reported in their experiment conducted in Van, average number of days to heading the obtained varied between 181.6 and 185.0 days in thirteen two-row barley cultivars. Insufficient rainfall in April-May during the experiment shortens the vegetation period and resulted in early spikes development. In general, early heading is a desirable trait for grains (Kaydan and Yagmur, 2007). Findings of Aydin and Katkat (1997) experiment indicates a positive relationship between grain filling and yield, as early heading increased yield. In contrast, Ulker et al. (1999) reported that the shortening of the heading stage in cereals affects grain filling period negatively.

Plant height values varied between 91.85 and 63.37 cm. The highest plants were measured in Akar with 91.85 cm followed by Anka-11 with 82.31 cm, whereas the shortest plants were measured in Anka-09 variety with 56.87 cm (Table 3). Plant height is greatly affected by factors such as soil fertility, planting density, humidity and temperature (Oral et al., 2017). In particular, the increase in the frequency and amount of irrigation encourages vegetative growth in plants and causes an increase in light competition, hence height (Topal, 1997). Furthermore, Kaydan and Yagmur (2007), and Oral et al. (2017) suggested that irrigation applied during the stem elongation and heading period, and Gultekin and Tokgoz (2008) mentioned that number of irrigations in barley farming affect plant height significantly. However, the increase in plant height due to excessive irrigation is not very desirable because it causes lodging.

The average number of spikes per square meter varied between 403.67 and 619.67. The highest number was obtained from Anka-11 and Anka-06 varieties, 619.67 and 593.67 respectively. The lowest number of spikes per square meter was measured in Avci 2002 variety with 403.67 (Table 3). Previously, it was reported by Sirat and Sezer (2011) that the number of spikes per square meter varied between 417.5 and 551.5 in Van ecological conditions, and under Samsun-Bafra plain condition Sirat and Sezer (2011) reported 394.6 to 547.5 spikes per square meter, while Coken (2016) stated that the number of spikes per square meter varied between 200-340. In these studies, it was suggested that different environmental and cultural practices as well as genetic variation of cultivars affects this parameter. It has been reported that the excessive increase in the number of spikes per square meter negatively affects other parameters such as thousand grain weight and grain yield (Kaydan and Yagmur, 2007; Oral et al., 2017).

Lodging in barley is an important factor that significantly reduces the yield and quality in the years when the rainfall exceeds 400 mm and the nitrogen fertilization is excessive. In the current experiment, lodging rate was observed only in Anka-11, Anka-06 and Tarm-92 cultivars (10%) (Table 3). The value of this parameter was low comparing to previous experiments, Coken (2016) reported up to 35% under Siirt ecological conditions, Aydogan and Ayranci (2013) reported up to 80% in Konya.

Chlorophyll concentration values varied between 45.34 and 53.09 SPAD units. The highest value was obtained from Tosunpasa and Akar cultivars, with SPAD values of 53.09 and 52.00 SPAD units, respectively. The lowest chlorophyll value was recorded in Anka-10 cultivar with a SPAD value of 45.34 SPAD units (Table 3). These values were higher compare to Kizilgeci et al. (2019) experiment (44.4 to 48.6 SPAD units) conducted in Diyarbakır and Mardin. Reynolds et al. (2001) indicated that genotypes with high SPAD values are more resistant to stress conditions. Thus, the rate and activity of photosynthesis increases which has a direct influence on yield and vice versa (Kizilgeci et al., 2019).

According to the data obtained, the longest period between heading to maturity was 36.7 and 36.0 days in Olgun and Larende cultivars, whereas Burakbey, Asil, Bozlak, Tosunpasa, Avci-2002, Aydanhanim, Akar, Anka-06, Anka-08 and Anka-11 varieties required a shorter period of time to reached maturity, 34.0 to 34.3 days (Table 3). Sirat and Sezer (2017) reported from their experiment in Samsun ecological conditions showed that maturity period in 2-row barley varieties varied between 40-46 days. In general, late maturation reduce the grain yield and thousand grain weight.

According to Table 3, the spike length values range between 7.30 and 9.96 cm. The longest spike was measured in Tosunpasa cultivar with 9.96 cm, followed by Bozlak with 9.80 cm and Akar with 9.46 cm. The shortest spikes were 7.30-7.60 cm in Olgun and Anka-09 cultivars, respectively. This parameter is highly affected by the environment and hereditary. In addition, it has been stated that cultural practices such as planting density, irrigation

and fertilization determine the increasing spike length (Kaydan and Yagmur, 2007; Kendal, 2016). Looking at the results obtained from the experiment, it was determined that tall cultivars had long spikes. Our findings were similar to another study conducted in similar cultivars and ecological conditions, it was stated that the spike length varied between 7.1 and 9.6 cm (Ongun, 2021).

The number of spikelets per spike among barley varieties varied between 33.8 and 21.7 (Table 3). Olgun had the highest value (33.8) followed by Avci-2002 (31.6) and Bozlak (31.5) varieties, whereas Anka-09 and Anka-08 had the lowest number of spikelets per spike, 21.7-22.3 respectively. It has been reported that there is a positive correlation between the number of spikelets and the number and weight of grains per spike (Akcura and Ceri, 2011; Altindal, 2014). Obtained results indicates that the number of grains and yield were high in varieties with high number of spikelets per spike.

Table 3. The averages of the data obtained from the observations in barley cultivars and the resulting groups

Variety	NDH (day)	PH (cm)	NSSM	LR (%)	CL (SPAD units)	MT (day)	S L(cm)	NSPS
Burakbey	169.33 cde	73.67 efgh	511.67 ef	0.0 c	50.86 bcd	34.3 c	9.10 cde	28.8 def
Larende	171.33 b	71.47 ghi	476.6 gh	0.0 c	47.23 ghi	36.0 ab	7.77 gh	23.0 i
Asil	169.00cdef	69.27 hi	585.33 b	0.0 c	48.67 ef	34.3 c	9.23 bcd	30 bcd
Bozlak	170.33 bc	79.60 bcd	470.00 h	0.0 c	46.20 ij	34.3 c	9.80 ab	31.5 b
Olgun	175.66 a	71.18 ghi	476.67 gh	0.0 c	51.85 ab	36.7 a	7.30 h	33.8 a
Çalabey	170.00 bcd	73.47efgh	511.67 ef	0.0 c	50.28 cd	35.0 bc	8.73 def	27.5 efg
Tosunpasa	167.67 fg	76.73 cdef	530.0de	0.0 c	53.09 a	34.0 c	9.96 a	31.3 bc
Avci-2002	175.33 a	63.37 j	403.67 i	0.0 c	50.87 bcd	34.0 c	8.43 efg	31.6 b
Tarm-92	171.00 b	72.38 fgh	524.0def	5.0 b	48.44 efg	35.0 bc	8.43 efg	25.5 gh
Aydanhanim	168.6defg	75.38defg	549.0 cd	0.0 c	47.83 fgh	34.0 c	8.83 cdef	29 cdef
Akar	168.00 efg	91.85 a	572.33bc	10.0 a	52.00 ab	34.0 c	9.46 abc	29.7bcde
Anka-06	167.33 g	81.13 bc	593.6ab	10.0 a	50.66 bcd	34.0 c	8.97 cdef	27.8 ef
Anka-08	169.33 cde	78.12bcde	510.00 ef	0.0 c	46.46 hij	34.3 c	8.33 fg	22.3 i
Anka-09	169.33 cde	56.87 k	498.00 fg	0.0 c	51.30 bc	34.7 bc	7.60 h	21.7 i
Anka-10	168.00 efg	67.27 ij	498.33 fg	0.0 c	45.34 j	34.0 c	7.93 gh	23.3 hi
Anka-11	168.67defg	82.31 b	619.67 a	10.0 a	49.78 de	34.3 c	8.40 fg	27.0 fg
Mean	169.93	74.01	520.66	2.20	49.42	34.5	8.50	28.5
CV (%)	0.47	4.04	3.08	3.23	1.68	1.72	4.82	4.71
LSD	0.58**	2.16**	11.61**	4.92*	0.60**	0.58**	2.22**	0.98**

*P<0.05 Level, ** P<0.01 significant level, CV (%): coefficient of variation, NDH: number of days to heading, PH: plant height, NSSM: number of spikes per square meter, LR: laying rate, CL: chlorophyll concentration, MT: maturation time, SL: spikes length, NSPS: number of spikelets per spike.

Plants differ in their temperature based on agrotechnicals factors such as plant density factors (Altuner, 2018). However, no differences in plant temperature were observed in the experiment, the value ranged between 30.0 to 30.4 ^{o}C (Table 4).

The number of fertile spikelets in 2-row cultivars was higher than in 6-row, and it varied between 7.13 and 15.73 (Table 4). Tosunpasa, Bozlak and Aydanhanim cultivars has the highest number of fertile spikelets and were in the same group with 15.40, 15.53 and 15.73 fertile spikelets, respectively, whereas Avci-2002 had the lowest number, 7.13. The number of fertile spikelets is directly related to the number of spikelets per spikes, the number of grains per spike, and grain yield, which is influenced by planting density, the number of main stem and tillers, environmental factors, genotype and environment interaction (Gecit, 1982; Kun, 1996; Kaydan and Yagmur, 2007). Hectolitre weight of the varieties varied between 62.30 – 66.10 kg/hl (Table 4). Akar genotype has the highest hectolitre weight of 66.10 kg/hl, followed by Tosunpasa with 65.66 kg/hl. The lowest hectolitre values obtained in the experiment were determined as 62.30 kg/hl from Anka-10. The values range of hectolitre in this study was higher from what Sari and Imamoglu (2009) obtained, 51 to 62 kg/hl, and lower from Coken (2016) findings, 66.2-76.36 kg/hl, and close to what Kendal (2016), Sirat and Sezer (2009) reported, 62.3 to 67.1 kg/hl and 62.6 kg/hl to

68.4 kg/hl respectively. This parameter is directly related to the protein ratio in the barley grain (Sirat and Sezer 2009). It has been reported that hectolitre weights vary depending on the homogeneous grain structure, husk and endosperm structure (Kun et al., 1992). Based on our results, the hectolitre weight obtained from 6-row varieties was below the average.

The biological yield values ranges were 20.45-15.59 t/ha (table 4). The highest biological yield was obtained from Anka-11 and Aydanhanim (20.36 and 20.45 t/ha) and they were within the same statical group. Akar, Olgun and Asil were followed in the same group (20.08, 20.01 and 20.08 t/ha). The lowest biological yield was measured from Anka-09 and Larende, 15.59 and 16.41 t/ha. Results obtained by Ongun (2021) from 17 barley cultivars under Van ecological conditions were much lower (3.467 to 6.172 t/ha) in compare to the current experiment. This might be due to the genotypes and supplemental irrigation as other previous scholars suggested (Gultekin and Tokgoz, 2008; Coken, 2016). Furthermore, our findings indicated that varieties with high plant height, number of spikes per square meter and grain yield values were generally high in biological yields.

Grain yield of barley cultivars varied between 3.08 and 6.98 t/ha (Table 4). In the experiment, Çalabey had the highest yields of 6.9867 t/ha, followed by Tosunpasa and Akar with 6.700 and 6.8069 t/ha, respectively. The lowest values were obtained from Anka-09 and Larende with 3.0868 and 3.3068 t/ha. Colkesen et al. (2002) reported close grain yield in different barley cultivars between 2.665-5.183 t/ha. Considering the results, it was observed that 2-row cultivars yield was higher than 6-row cultivars. The 6-row varieties being more sensitive to cold in winter planting than 2-row cultivars (Coken, 2016).

Table 4. The averages of the data obtained from the observations in barley cultivars and the formed groups

Variety	PT(°C)	NFSS	TGW (g)	HW (kg/hl)	BY (t/ha)	GY (t/ha)	HI (%)
Burakbey	30.2	14.27 bc	39.80 ef	62.96 hi	18.30 def	5.06 ef	27.3 fg
Larende	30.0	11.87 de	36.70 h	65.43 bcd	16.41 g	3.30 g	20.6 h
Asil	30.1	14.20 bc	42.60 d	65.53 bcd	20.01 ab	6.59 abc	32.7 abc
Bozlak	30.2	15.53 a	45.83 a	63.76 fg	19.05 cd	5.23 ef	27.4 efg
Olgun	30.4	8.40 f	45.40 ab	63.80 fg	20.00 ab	5.57 cdef	27.5 efg
Çalabey	30.2	13.87 c	37.60 gh	65.60 bcd	17.90 f	6.98 a	31.0 cd
Tosunpasa	30.1	15.73 a	44.97 ab	65.66 ab	19.23 bc	6.70 ab	34.6 a
Avci-2002	30.0	7.13 g	43.80 bcd	63.26 gh	18.65 cdef	6.50 abcd	34.4 ab
Tarm-92	30.4	12.17 d	39.77 ef	65.13 cd	17.65 f	5.28 def	29.7 de
Aydanhanim	30.1	15.40 a	38.80 fg	64.93 de	20.36 a	5.84 bcde	33.5 ab
Akar	30.2	15.06 ab	44.73 abc	66.10 a	20.08 ab	6.80 ab	33.4 ab
Anka-06	30.0	14.13 bc	41.03 e	63.56 gh	19.24 bc	6.34 abcd	32.9 abc
Anka-08	30.0	12.07 de	37.06 h	64.36 ef	18.77 cde	5.56 cdef	29.5 def
Anka-09	30.4	11.07 e	36.67 h	63.50 gh	15.59 g	3.08 g	20.4 h
Anka-10	30.2	12.43 d	37.83 gh	62.30 i	18.18 ef	4.63 f	25.5 g
Anka-11	30.2	13.73 c	43.47 cd	65.36 cd	20.45 a	6.40 abc	31.8 bcd
Mean	30.2	12.93	41.01	64.47	18.76	5.62	29.9
CV (%)	4.22	5.02	5.50	0.48	3.42	11.50	3.47
LSD	0.34 ns	0.47**	0.58**	0.30**	0.18**	46.49**	1.01**

*P<0.05 Level, ** P<0.01 significant level, CV (%): coefficient of variation, PT: plant temperature, NFSS: number of fertile spikelets per spike, GW: 1000 grain weight, HW: hectolitre weight, BY: biological yield, GY: grain yield, HI: harvest index

Correlation between parameters

The relationship between studied parameters is presented in Table 5. The correlation between NDH and MT was found to be positive and significant, whereas the correlation was negative and significant with NSSM and NFSS. The correlation between PH and NSSM, LR, SL, NFSS, BY, and GY was positive and significant. NSSM correlation with LR and NFSS was significant and positive, while it was negative and significant with MT. The PT correlation with CL and GY was significant and positive. MT correlation with CL and NFSS was negative and significant. SL had a

significant positive correlation with NFSS, GY and HI. A positive correlation was found between NSPS with BY, GY, HI, TGW. Finally, the correlation among BY, GY, HI, TGW, was positive and significant. Similar to this study, Al-Menaie et al. (2021) found a positive correlation of PH with BY, GY, TGW, and NSSM, whereas it was negatively correlated with HI. Furthermore, Von Koff et al. (2008) reported a positive correlation between PH and LR. and a negative correlation between PH and GY.

Table 5. The correlation among the measured parameters

	NDH	PH	NSSM	LR	PT	CL	MT	SL	NFSS	NSPS	BY	GY	HI	TGW	HW
NDH	1														
PH	-0,41	1													
NSSM	-0,71**	0,56*	1												
LR	-0,35	0,65**	0,67**	1											
PT	0,11	0,49	0,07	0,33	1										
CL	0,11	0,06	0,12	0,25	0,50*	1									
MT	0,97**	-0,39	-0,66**	-0,35	0,09	0,11	1								
SL	-0,48	0,55*	0,31	0,17	0,17	0,14	-0,56*	1							
NFSS	-0,83**	0,60*	0,63**	0,24	-0,01	-0,09	-0,80**	0,75**	1						
NSPS	0,35	0,26	-0,04	0,00	0,29	0,45	0,28	0,46	0,04	1					
BY	-0,09	0,61*	0,47	0,35	0,31	0,12	-0,14	0,43	0,30	0,67**	1				
GY	-0,09	0,53*	0,37	0,35	0,50*	0,36	-0,17	0,57*	0,26	0,62**	0,75**	1			
HI	-0,11	0,46	0,36	0,36	0,48	0,27	-0,22	0,55*	0,22	0,55*	0,74**	0,92**	1		
TGW	0,23	0,40	0,06	0,27	0,15	0,41	0,16	0,47	0,06	0,85**	0,66**	0,55*	0,52*	1	
HW	-0,21	0,47	0,46	0,28	0,31	0,21	-0,14	0,33	0,41	0,10	0,25	0,40	0,40	0,14	1

*P<0.05 Level, ** P<0.01 significant level, number of days to heading (NDH), plant height (PH), number of spikes per square meter (NSSM), lodging rate (LR), plant temperature (PT), chlorophyll concentration (CL), physiological maturity (MT), spike length (SL), number of fertile spikelets per spike (NFSS), number of spikelets per spike (NSPS), biological yield (BY), grain yield (GY), harvest index (HI), 1000 grain weight (TGW), and hectolitre weight (HW).

CONCLUSIONS

This study was carried out to determine the capacity of adaptability of two and six row barley varieties under irrigated conditions in Van ecological conditions. It has been observed that the average grain and total yield (5.62 and 18.76 t/ha) obtained with the supplementary irrigation equivalent to 114 mm precipitation. This increased yield over 30% compared to dry conditions (1.99 and 4.4 t/ha). In Van, where global warming and related drought are experienced intensely, it has been concluded that high yields can be obtained in cereal crop with supplemental irrigation. Based on our experiment findings, it is thought that it would be more accurate implement longer field trials and more genotypes in order to reach convinced findings.

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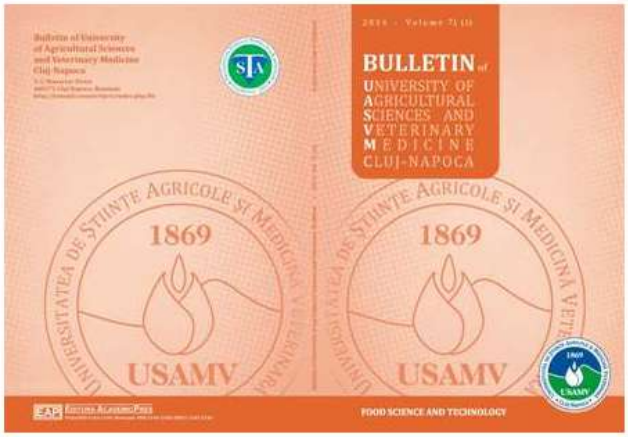
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University of Agricultural Sciences and Veterinary Medicine
3-5 Manastur St., 400372 Cluj-Napoca
Romania
Tel: +40-264-596.384 | Fax: +40-264-593.792
biroupublicatii@usamvcluj.ro