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Original article

Effect of sowing depth on qualitative characteristics tuber yield and water use efficiency of potato cultivars in autumn and spring cultivations of moderate and cold regions

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Extended abstract

Introduction

The scientifically named potato (*Solanum tuberosum* L.) is one of the most important agricultural products in the world that belongs to the Solanaceae family, an autotetraploid plant (2n=4x=48), with complex inheritance patterns and in terms of nutritional importance, it ranks fourth after wheat, rice and maize and plays an important role in the nutrition and food basket of the global population. This research aims of this study was to investigate the effect of planting date and planting depth on some quality traits, glandular function and water use efficiency of potato cultivars in autumn and spring cultivation of temperate cold region in Araloo Agricultural Research and Natural Resources Station farm in Ardabil region for 2 years (2017-2018).

Materials and methods

Split-factorial experiment based on complete randomized block design in three replications of planting date at three levels (10 Novomber, 10 December and 10 May) as the main factor and factor combination of four potato cultivars (Sprite, Marfona, Savalan and Agria) And four planting planting depths (10, 15, 20 and 25 cm) were considered as a secondary factor. After performing the normality of the data and the experimental error uniformity of the compound analysis based on the statistical factor design and comparing the mean based on the LSD test at 5% probability level by SAS9.1 software and correlation between traits using Minitab.16 software. And the graphs were drawn with Excel software.

Results

The results of analysis of variance of the evaluated traits showed that the simple effect of planting date (gland function and water use efficiency) and simple effect of planting depth (nitrogen content, fiber percentage and soluble sugars) had a statistically significant difference between 5 and 1% probability. In terms of the quadrilateral effect A×B×C×D, the traits (percentage of dry matter and soluble sugars) had a significant difference. Water Use efficiency was higher in November and December planting at depths of 10, 15 and 25 with the number of sprays with water efficiency of 6 (kg/m^3).The average yield of the tuber in Marfona cultivar was 30 tons per hectare in May and 24 tons per hectare in November

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cultivation and 20 tons per hectare in December cultivation. The difference in glandular function between spring and autumn planting was on average 8 tons per hectare. Meanwhile, in the autumn cultivation, about 4551 cubic meters per hectare (4 irrigations) and in the spring, about 14214 cubic meters per hectare (12 irrigations) were done. In this study, the number of irrigation times in autumn and spring planting was reduced from 12 irrigations to 4 irrigations and the difference in water consumption was 9663 cubic meters per hectare.The gland with the traits of the percentage of glandular starch and the percentage of fiber of the gland was negative and significant and with the percentage of dry matter of the gland was positive and significant .

Conclusions

Finally, it can be concluded that autumn cultivation of potato is suitable, especially in areas with water shortages. The highest water use efficiency in autumn cultivation at depths of 10, 15 and 25 cm was related to the Esprit cultivar.

***Keywords*:** Autumn and Spring Cultivation, Potatoes, Qualitative Characteristics, Water Use Efficiency

Table 1. Characteristics of the cultivars cultivated in the design

Cultivars	Growth period	Type of Use	Tuber flesh color
Esprit	Mid-late	Fresh consumption	Light yellow
Marfona	Mid-late	Fresh consumption	Light yellow
Savalan	Mid-late	French Fries	Light yellow
Agria	Mid-late	French Fries	yellow

Table 2. Using water amount in different potato cultivations through surface irrigation with WSC-Flume type4

Year	Ultivatcion	Number of irrigation	using water amount	Effective rain amount	* Practical water volume
			----------$m^3.ha^{-1}$----------		
2017	Autumn and winter	4	4015	441	4456
	Spring	13	13699	562	14261
2018	Autumn and winter	14	3950	696	4646
	Spring	12	13150	1017	14167

Table 3. Leven test values to test the experimental errors of the studied traits

water use efficiency (WUE)	yieldtotal tuber (ton/ha)	Percentage Starch of Tuber	Nitrogen of tuber	Percentage fiber of Tuber	Tuber dry matter	percentage of soluble sugars
0.537^{ns}	0.631^{ns}	8.247^{**}	13.518^{**}	15.425^{**}	12.695^{**}	16.799^{**}

Table 4. Analysis of variance of variance. Effect of date and sowing depth on tuber yield and qualitative traits in potato

S.O.V	df	Percentage Starch of Tuber	Nitrogen of tuber	Percentage fiber of Tuber	Tuber dry matter
Year (A)	1	2.042 ^{ns}	0.065 ^{ns}	0.025 ns	4.009 ^{ns}
Error 1	4	0.277	0.034	0.036	0.746
Planting Date (B)	2	0.624 ^{ns}	0.042 ^{ns}	0.028 ^{ns}	17.943 ^{ns}
A × B	2	0.623 ^{ns}	0.042 ^{ns}	0.027 ^{ns}	1.079 ^{ns}
Error 2	8	0.357	0.034	0.025	0.692
Planting Depth (C)	3	0.279 ^{ns}	0.014*	0.023**	2.524 ^{ns}
A × C	3	0.129 ^{ns}	0.012 ^{ns}	0.008 ^{ns}	4.929*
B × C	6	0.07 ^{ns}	0.004 ^{ns}	0.004 ^{ns}	5.009**
A × B × C	6	0.07 ^{ns}	0.004 ^{ns}	0.004 ^{ns}	3.29 ^{ns}
Variety (D)	3	21.996**	0.197**	0.034**	273.653**
A × D	3	1.612**	0.024**	0.006 ^{ns}	0.394 ^{ns}
B× D	6	2.869**	0.021**	0.01 ^{ns}	14.889**
A × B × D	6	2.869**	0.021**	0.01 ^{ns}	1.918 ^{ns}
C × D	9	1.188**	0.006 ^{ns}	0.007 ^{ns}	2.861 ^{ns}
A × C × D	9	0.329*	0.005 ^{ns}	0.008 ^{ns}	1.681 ^{ns}
B × C × D	18	0.322 ^{ns}	0.055**	0.006 ^{ns}	5.604 ^{ns}
A × B × C × D	18	0.321**	0.005 ^{ns}	0.006 ^{ns}	2.742 ^{ns}
Error 2	180	0.155	0.005	0.005	1.662
C.V%		*2.79*	*3.27*	*3.37*	*6.43*

Table 4. Continued

S.O.V	df	percentage of soluble sugars	yieldtotal tuber(ton/ha)	water use efficiency (WUE)
Year (A)	1	0.001 ^{ns}	1.021 ^{ns}	0.587 ^{ns}
Error 1	4	0.00024	72.527	1.639
Planting Date (B)	2	0.000282 ^{ns}	2179.495**	26.983*
A × B	2	0.000382 ^{ns}	1.123 ^{ns}	0.316 ^{ns}
Error 2	8	0.000187 ^{ns}	114.575	3.884
Planting Depth (C)	3	0.002**	337.039**	2.707 ^{ns}
A × C	3	0.000085 ^{ns}	3.041 ^{ns}	0.67 ^{ns}
B × C	6	0.000487**	176.274**	2.506 ^{ns}
A × B × C	6	0.000293 ^{ns}	2.701 ^{ns}	0.385 ^{ns}
Variety (D)	3	0.000257 ^{ns}	10.233 ^{ns}	10.013**
A × D	3	0.00008 ^{ns}	0.443 ^{ns}	4.365 ^{ns}
B× D	6	0.000481 ^{ns}	114.1277**	8.52 ^{ns}
A × B × D	6	0.000329 ^{ns}	0.224 ^{ns}	3.955 ^{ns}
C × D	9	0.000134 ^{ns}	52.699**	3.220 **
A × C × D	9	0.000159 ^{ns}	1.53 ^{ns}	0.88 ^{ns}
B × C × D	18	0.000335 ^{ns}	30.583**	2.037*
A × B × C × D	18	0.000338*	1.334 ^{ns}	0.845 ^{ns}
Error 2	180	0.000167	14.272	2.065
C.V%		9.17	16.76	21.10

*,**, ns:Significant at 5 and 1% level of probability and Non significant, respectively.

Table 5. Comparison of the average simple effect of cultivation depth and cultivar on the traits evaluated by potato tuber

Simple effects	Traits	
Planting Depth	**Nitrogen og tuber (%)**	**Fiber of tuber (%)**
10 cm	2.095 [b]	2.103 [a]
15 cm	2.128 [a]	2.107 [a]
20 cm	2.117 [ab]	2.102 [a]
25 cm	2.112 [ab]	2.069 [b]
Genotypes		
Sprit		2.083 [ab]
Marfona		2.114 [a]
Savalan		2.07 [b]
Agria		2.113 [a]

Table 6. Comparison of the mean of the three-way effect planting date, cultivar, depth

Genotype× Depth × Data			yield of potato tuber	water use efficiency (WUE)	percentage of dry matter
10 Aban (Nov)	10cm	Sprit	25.3 d-h	5.56 ab	20.785 b-f
		Marfona	18.3 h-o	4.11 c-j	15.612 i
		Savalan	24.3 d-h	5.43 abc	22.07 a-d
		Agria	24.5 d-h	5.5 abc	21.12 b-f
	15cm	Sprit	27.4 c-f	6.15 a	20.04 c-f
		Marfona	21.1 e-l	4.74 a-gj	16.05 i
		Savalan	25.2 d-h	5.66 ab	22.09 a-d
		Agria	18.9 g-n	4,24 b-i	20.34 c-f
	20cm	Sprit	18.6 h-o	4.17 b-j	21.88 a-d
		Marfona	13.2 l-o	2.96 i-p	15.55 i
		Savalan	14.8 n-o	3.32 g-n	20.86 b-f
		Agria	21.4 e-l	4.18 a-g	20.16 c-f
	25cm	Sprit	22.7 e-j	5.10 a-d	21.76 a-d
		Marfona	20.9 e-m	4.69 a-g	16.78 hi
		Savalan	21.4 e-l	4.79 a-g	21.93a-d
		Agria	22 e-k	4.94 a-e	20.18 c-f
10 Azar (Dec)	10cm	Sprit	12.2 o	2.73 j-p	19.82 def
		Marfona	15.1 l-o	3.39 f-n	16.33 i
		Savalan	16.6 j-o	3.73 d-l	20.30 c-f
		Agria	22.4 e-j	5.02 a-d	20.25 c-f
	15cm	Sprit	24.3 d-h	5.46 abc	21.02 b-f
		Marfona	22.8 e-j	5.11 a-d	16.75 hi
		Savalan	20.7 f-m	4.64 b-h	22.23abc
		Agria	21.2 e-l	4.76 a-g	21.34 a-e
	20cm	Sprit	17.3 i-o	3.89 d-k	18.78 fgh
		Marfona	16.8 j-o	3.76 d-l	17.11 ghi
		Savalan	20.3 g-m	4.56 b-h	21.76 a-d
		Agria	19.8 g-n	4.45 b-h	20.49 c-f
	25cm	Sprit	21.5 e-l	4.84 a-f	22.26 abc
		Marfona	16.3 j-o	3.65 d-l	16.29 i
		Savalan	14.2 mno	3.18 h-o	21.39a-d
		Agria	15.4 k-o	3.45 e-m	20.35 c-f
10 Ordibehesht (May)	10cm	Sprit	29.6 a-d	2.15 m-p	21.06 b-f
		Marfona	35.9 a	2.56 k-p	18.84 fgh
		Savalan	33.9 ab	2.42 l-p	23.36 a
		Agria	30.2 a-d	2.16 m-p	21.27 a-e
	15cm	Sprit	27.3 c-f	1.95 nop	21 b-f
		Marfona	32.4 abc	2.31 l-p	19 efg
		Savalan	30.3 a-d	2.16 m-p	20 c-f
		Agria	25.8 d-g	1.84 op	21.12 b-f
	20cm	Sprit	24.6 d-h	1.79 op	21 b-f
		Marfona	27.5 c-f	1.96 nop	19 efg
		Savalan	27.7 b-e	1.98 nop	20 c-f
		Agria	24.6 d-h	1.75 op	21 b-f
	25cm	Sprit	24.1 d-i	1.72 op	20 c-f
		Marfona	25 d-h	1.79 op	19 efg
		Savalan	24.3 d-h	1.74 o-p	23 ab
		Agria	22.1 e-k	1.57 p	20 c-f

Table 7. Comparison of the mean of quadrilateral effects (year × planting date × planting depth × cultivar) on the traits evaluated by potato tuber

(Yaer × Data × Depth × Genotype)			Traits			
			Starch of Tuber		soluble sugars	
			Year 1	Year 2	Year 1	Year 2
10 Aban (Nov	10cm	Sprit	14.450^{a-f}	14.07^{e-m}	14.927^{a-e}	0.207^{a-e}
		Marfona	13.200^{k-o}	12.867^{no}	13.253^{j-o}	0.193^{b-e}
		Savalan	14.400^{a-f}	14.773^{a-e}	14.327^{a-h}	0.210^{a-e}
		Agria	14.650^{a-e}	14.483^{a-f}	14.527 $^{a-f}$	0.203^{a-e}
	15cm	Sprit	14.400^{a-f}	14.067^{e-m}	15.153^{a-d}	0.210^{a-e}
		Marfona	13.300^{h-n}	13.300^{h-n}	13.135^{l-o}	0.223^{ab}
		Savalan	14.300^{a-h}	14.167^{c-l}	14.153^{c-l}	0.223^{a-d}
		Agria	14.600^{a-e}	14.267^{a-j}	14.153^{c-l}	0.223 ^{ab}
	20cm	Sprit	14.927^{a-e}	15.260^{ab}	14.017^{e-m}	0.193^{b-e}
		Marfona	13.250^{j-o}	12.250^{op}	12.667^{no}	0.213^{a-d}
		Savalan	14.327^{a-h}	14.100^{c-m}	14.733^{a-e}	0.207^{a-e}
		Agria	14.527^{a-f}	14.527^{a-f}	14.483^{a-f}	0.193^{b-e}
	25cm	Sprit	15.150^{a-d}	15.167 ^{bc}	14.067^{e-m}	0.207^{a-e}
		Marfona	13.150^{l-o}	13.267 $^{i-n}$	13.300^{h-n}	0.183^{d-e}
		Savalan	14.150^{c-l}	14.083^{d-m}	14.167 $^{c-l}$	0.213^{a-d}
		Agria	14.150^{c-l}	13.483^{f-n}	14.267 $^{a-j}$	0.177^{e}
10 Azar (Dec)	10cm	Sprit	14.453^{a-f}	14.320^{a-h}	15.260^{ab}	0.187^{cde}
		Marfona	13.200^{k-o}	11.807^{p}	12.250^{op}	0.220^{abc}
		Savalan	14.400 $^{a-f}$	14.280^{a-i}	14.100^{c-m}	0.197 $^{a-e}$
		Agria	14.653^{a-e}	14.203^{b-k}	14.527^{a-f}	0.213^{a-d}
	15cm	Sprit	14.400^{a-f}	14.343^{a-g}	15.167^{bc}	0.223^{ab}
		Marfona	13.300^{h-n}	12.977^{no}	13.267^{i-n}	0.217^{a-d}
		Savalan	14.300^{a-h}	14.543^{a-f}	14.083^{d-m}	0.223^{ab}
		Agria	14.600^{a-e}	14.003^{e-m}	13.483^{f-n}	0.197^{a-e}
	20cm	Sprit	14.927^{a-e}	15.290 ^{a}	14.320^{a-h}	0.213^{a-d}
		Marfona	13.253 $^{j-o}$	3.087^{mno}	11.807^{p}	0.213^{a-d}
		Savalan	14.327^{a-h}	13.227^{k-o}	14.028^{a-i}	0.187^{cde}
		Agria	14.527 $^{a-f}$	14.390 $^{a-f}$	14.203^{b-k}	0.210^{a-e}
	25cm	Sprit	15.153^{a-d}	14.477^{a-f}	14.343^{a-g}	0.183^{d-e}
		Marfona	13.153^{l-o}	13.187^{k-o}	12.977^{no}	0.210^{abc}
		Savalan	14.153^{c-l}	14.363^{a-f}	14.543^{a-f}	0.177^{e}
		Agria	14.153^{c-l}	13.320^{g-n}	14.003^{e-m}	0.207^{a-e}
10 Ordibehesht (May)	10cm	Sprit	14.453^{a-f}	13.150^{l-o}	15.290 ^{a}	0.227^{ab}
		Marfona	13.200^{k-o}	14.150^{c-l}	3.087^{mno}	0.217^{a-d}
		Savalan	14.400 $^{a-f}$	14.150^{c-l}	13.227^{k-o}	0.210^{a-e}
		Agria	14.653^{a-e}	14.450^{a-f}	14.390^{a-f}	0.210^{a-e}
	15cm	Sprit	14.40 a-f	13.200^{k-o}	14.447 $^{a-f}$	0.200^{a-e}
		Marfona	13.30 $^{h-n}$	14.400 $^{a-f}$	13.187^{k-o}	0.207^{a-e}
		Savalan	14.30 $^{a-h}$	14.650^{a-e}	14.363^{a-f}	0.197^{a-e}
		Agria	14.60 $^{a-e}$	14.400^{a-f}	13.320^{g-n}	0.210^{a-e}
	20cm	Sprit	14.927^{a-e}	13.300^{h-n}	0.230 ^{a}	0.210^{a-e}
		Marfona	13.253^{j-o}	14.300^{a-h}	0.213^{a-d}	0.203^{a-e}
		Savalan	14.327^{a-h}	14.600^{a-e}	0.213^{a-d}	0.217^{a-d}
		Agria	14.527^{a-f}	14.927^{a-e}	0.197^{a-e}	0.220^{abc}
	25cm	Sprit	15.153^{a-d}	13.250^{j-o}	0.207^{a-e}	0.217^{a-d}
		Marfona	13.153^{l-o}	14.327^{a-h}	0.200^{a-e}	0.213^{a-d}
		Savalan	14.153^{c-l}	14.527^{a-f}	0.207^{a-e}	0.217^{a-d}
		Agria	14.153^{c-l}	15.150^{a-d}	0.197^{a-e}	0.207^{a-e}

Table 8. Correlation between of evaluated traits in cultivars

	Correlation coefficient	1	2	3	4	5	6
1	**Nitrogen of tuber**	1					
2	**Starch of Tuber**	0.127*	1				
3	**Fiber of Tuber**	0.213**	0.076	1			
4	**Tuber dry matter**	0.233**	-0.586**	-0.478**	1		
5	**Soluble sugars**	-0.072	0.108	0.083	0.073	1	
6	**Total tuber yield**	-0.086	-0.079	-0.084	-0.017	-0.039	1
7	**WUE**	0.06	-0.088	-0.065	-0.092	-0.063	-0.089

*, ** Significant at p≤0.05 and 0.01, respectively