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Evaluation of advanced potato clones derived from breeding program in spring cultivated areas of Iran

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ABSTRACT

During this research the selected hybrid and open pollinated potato clones were evaluated in three regions including Karaj, Hamadan and Ardabil of Iran. Quantitative and qualitative traits of the potato clones in the field experiments were recorded and analyzed in comparison to the check potato cultivar Agria.

The results of combined analysis of places showed that among studied plant materials, 13 potato clones yielded more than others and check cultivar. About half of these potato clones had the least unfit tubers and their marketable tubers yielded equal or more than 30 ton/ha. Most of potato clones with the highest marketable tuber were amongst the superior ones in terms of the number of main stems. In this research, except for number of tuber per plant, other traits significantly correlated with total and marketable yield. Interestingly, three potato clones among those with the highest amount of marketable yield, produced maximum number of tuber per plant. The content of dry matter in these clones was more than 22%, also. Totally, among studied potato clones in this research, nine clones with good agronomical traits and suitable external characteristics were selected as promising clones for fresh consumption or industrial utility.

KEY WORDS: POTATO, CLONE, BREEDING, QUANTITATIVE AND QUALITATIVE TRAITS.

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INTRODUCTION

Potato (*Solanum tuberosum*) has been accounted as the third most important food crop after wheat and rice (Haverkort et al., 2009). Potatoes were introduced into Europe in the 1570s, from Andes region and coastal Chile. After a short time, this crop became widespread in whole Europe and beyond to other parts of the world (Hawkes and Francisco-Ortega, 1993; Pandey and Kaushik, 2003). Despite many potato cultivars available in different sites, introducing of new varieties with desirable traits have been considered as a prior goal by breeders. The new varieties must have been equipped with some characters such as: yielding more marketable potato with the minimum cost of producing, getting the least damage from attack of pests and diseases, having enough tolerance to the environmental stresses and giving more economical benefit than the current varieties. Two basic steps are mentioned as premier ones in potato breeding program: 1) selecting of superior parents for crossing 2) selecting of derived clones with desirable properties from segregating progenies (Gopal, 2015).

The first step in the plant breeding is creating a population which contains sufficient variation in the respected traits (Tabanao and Bernardo, 2005). The variation between plant materials provides the effective selection. This variation could be created naturally through open pollination or artificially through hybrid and more variation lead to better discriminating, which is favourable in the plant breeding (Jozani et al., 2003).

In conventional potato breeding program, both hybridization and open pollination (OP) could be used for producing breeding population. However, clones derived from hybrid usually produce tubers which are more uniform, larger in size and have favorite quantity and quality traits (Macaso-Khwaja and Peloquin, 1983).

Many different factors are involved in the crossing between parents of potato in the hybridization method. These could be counted as flowering, incompatibility, ploidy level, endosperm balance number, heterozygosity, general combining ability and specific combining ability (Bonierbale, 2007; Muthoni et al., 2014; Gopal, 2015). The selection of parents depends on the objective of breeding program. New techniques and approaches in plant breeding make it possible to hybridize different potato genotypes in spite of limitation in crossing (Muthoni et al., 2014). The main principle for breeding is developing new cultivars which inherit good traits of their parents. For this reason, it would be more achievable when potato cultivars with complementary features used as parents to create progenies and derived clones with desirable traits. However, in some cases there is no prior knowledge about the outcome of the crosses. So, for compensating this defect and maximizing the number of derived clones with good characters, the number of cross combination should be increased (Grüneberg et al., 2009).

Potato breeding in different countries could be divided into four to five main steps, on the basis of national potato breeding programin successive years. The including steps are choosing the appropriate parents, crossing, primary evaluation of segregating population, advanced and adaptability experiments. After crossing between the appropriate parents, the primary evaluation could be done in the net-houses and small scales of experimental field. Derivative potato clones are multiplied and evaluated more detail in advanced and adaptability experiments in different locations (Neele, 1991; Douches et al., 2001; Clough et al., 2010). Multi-location variety trails are generally done on the selected potato clones to evaluate their uniformity, qualitative and qualitative traits and resistance to important regional diseases and pests. Therefore, adaptability and stability of selected clones are usually studied in locations with different environmental condition in order to determining their capabilities (Bradshaw et al., 2006; Bonierbale, 2007).

In this research, quantitative and qualitative traits of 21 potato clones derived from 8 hybrids and 2 open pollinated populations in the previous experiments were studied in three different production regions in Iran.

MATERIAL AND METHODS

IMPLEMENTATION OF FIELD EXPERIMENT

Selected potato clones in the preliminary study derived from crossing between commercial cultivars and OP population of potatoes were evaluated in advanced experiment (table 1). The clones were qualitatively and quantitatively compared with cultivar Agria as check cultivar in the experiment in three production site including Karaj, Hamadan, and Ardabil in Iran. The experiment was conducted according to the randomized complete block design (RCBD) with twenty one treatments as clones and cultivar with three replications, in each site. The clones were planted in the plot with two 5 meter length sowing rows with density of 25 × 75cm and planting depth of 10cm.

ASSESSMENT OF TRAITS IN THE EXPERIMENT

During the growth of potato clones in the field, some agronomical and morphological characters such as plant height, number of main stems, growth habit and length of growth period were recorded. Five plants in each plot were considered randomly and the mentioned characters were calculated. Among the characters, growth habit is a morphological trait and was recorded during forming of

Table 1. List of studied potato clones derived from different hybrids and open pollinations.

No.	Potato clone no.	Pedigree	No.	Potato clone no.	Pedigree
1	6001	Ajax × Kufri Jyotii	11	8005	Zolushka (OP*)
2	6003		12	25020	Kufri Bahar × Kufri Jyotii
3	5504	Desiree ×Marfona	13	2508	
4	5502		14	2501	
5	5503		15	3503	Kufri Bahar × Concorde
6	5505		16	3504	
7	75013	Khorasan clones (OP*)	17	3501	
8	75011		18	3505	
9	7508		19	1502	Kufri Badeshah × Kufri Bahar
10	1001	Ajax × Concorde	20	4005	× Kufri Jyotii Kufri Badeshah

*OP : Open pollination

blossom to flowering of 50% of plants.Length of growth period of clones was the time between sowing date till physiological maturity which was indexed with natural yellows of foliage decline at the end of growing season.

After harvesting of potato clones, other agronomical traits including total yield, marketable yield, number and weight of tuber per plant, percent of dry matter were calculated.

To measure the marketable yield, the tiny tubers (less than 28 mmin diameter) and rotted ones were separated, then weighted and decreased from the total yield of each plot. Total weight and number of tuber in each plot were divided to the total number of plants in that plot and resulted in number and weight of tuber per plant. To determine percentage of dry matter, slices of four random normal tubers of each plot with medium size were prepared and weighted before and after drying in oven with $75^{\circ c}$ for 48 hours. Then percentage of dry matter was calculated with the below formula:

DM% = Wd / Wf ×100
DM: Percentage of dray matter
Wd: weight of dried slices
Wf: weight of fresh slices)

Normal tuber of each clones without any physiological and biotic symptoms were chosen from the harvested plots and external characters like color of skin and flesh, tuber form, eye depth were alsodetermined.

2.3. Statistical analysis of experimental data

Data of agronomical traits in every region were recorded and statistically analyzed with SAS software ver.9. The combined analysis of variance (CANOVA) for each trait in all regions was computed and comparison of means was done with Duncan test. The correlation among traits in the experiment was done by the use of spearman rating method, and positive or negative type of correlation and its significance were determined (Zar, 1999).

RESULTS AND DISCUSSION

Combined analysis of variance of experimental data in all locations showed that there is a significant difference at probability level 1% (P < 1%) between potato clones × regions in agronomical traits including total yield, marketable yield, number of main stems, plant height and number of tuber per plant. The trait percentage of dry matter was only significant at probability level 5% (P < 5%) in this concern (table 2).

According to the results of the comparison mean of agronomical traits, potato clones 2501, 8005, 1502 and 6003 had the yield in the ranges between 35.19- 41.22 t./ha.These clones were significantly superior than check cultivar, Agria, with 28.58 t./ha. and other potato clones (table3). There was another group of potato clones including 2508, 3504, 6001, 5504, 7508, 3505, 5503, 75013 and 25020 which didn't have significant difference with Agria. However their yield increment to the check, were in a wide range from 3% to 18%. By subtracting the tiny and rotted tubers from the whole products and comparing the marketable product of potato clones, it was noticed that clones no. 8005, 2501, 6003, 2508, 3504, 5504 and 6001 had the least amount of unfit tubers.

Amount of dry matter in two superior clones including 6003 and 6001 derived from hybrid Ajax × Kufri Jyotii with 27.29% and 23.45% and one clone "75013"

Table 2. Combined analysis of variance of data from the studied traits of potato clones in the regions

Source of Variation	DF1	Total yield2	Marketable yield2	No. of Stems /plant2	Dry matter 2	Plant height2	No. of tubers /plant 2
Potato clones	20	143.283**	120.525**	1.067**	33.559**	132.084**	15.548**
region	2	2103.669**	3087.966**	11.421**	296.743**	1215.498**	66.934**
Replication× region	6	146.207**	146.797*	1.741**	42.774**	132.084**	4.129ns
Potato Clone × region	40	84.555**	100.587**	1.463**	20.838*	144.066**	6.695**
Error	12	44.847	55.301	0.462	14.076	50.959**	3.155

1: Degree of freedom
2: Data are mean squares of the traits
ns, *,**: Not significant and significant at 1% and 5% probability level, respectively.

from OP, Khorasan, significantly differed from other clones and the check.

Amount of the marketable yield in the superior clones were in the range between 29.27 -37.79. On the other hand, potato clone 75011 and cultivar Agria with 24.47 and 25.74 t/ha. respectively, had the least amount of marketable yield.

The results of number of main stem per plant indicated that 12 potato clones had 4 or more main stems and grouped statistically in class A. Except for two superior potato clones in marketable yield, the rest were among the superior ones in the trait, number of main stems.

The height of eleven potato clones was in the same level as Agria. However about half of these clones were taller than others and their heights were in the range of 60 to 65.16 centimeter (table 3).

Another index for determining the potential of a potato clone is the number of tubers produced by single plant which negatively correlate with the yield (table 4).

Table 3. Mean comparison of data from different traits of the potato clones in three regions with Duncan test

No.	Potato clones	Total yield (Ton/ha.)		Marketableyield (Ton/ha.)		No.main stems		Dry Matter (percent)		Plant height (cm)		No. tubers/ plant	
1	75013	29.71	cdef	28.66	cd	4.12	abcd	23.79	abc	56.63	bcd	10.75	abc
2	1001	30.22	cdef	28.68	cd	4.24	a	22.71	cd	55.13	cd	8.55	efgh
3	1502	35.19	abc	33.98	abc	3.44	bcde	22.39	cd	65.16	a	8.42	efgh
4	8005	40.15	ab	37.79	a	4.22	ab	21.26	cd	57.59	abcd	8.92	cdefgh
5	4005	27.99	cdef	25.96	cd	3.53	abcde	21.12	cd	53.97	cd	8.87	cdefgh
6	7508	30.63	cdef	29.13	bcd	4.01	abcd	20.54	cd	60.32	abc	10.52	abcd
7	3505	30.53	cdef	27.61	cd	4.08	abcd	21.52	cd	52.94	cd	10.21	abcdef
8	25020	29.32	cdef	25.78	cd	4.16	abc	19.13	d	59.80	abc	10.14	abcdef
9	3504	32.28	cdef	30.31	abcd	4.16	abc	22.17	cd	55.83	cd	10.33	abcde
10	6001	31.13	cdef	29.27	abcd	4.05	abcd	27.29	a	64.77	ab	11.47	ab
11	3503	26.83	ef	26.81	cd	3.83	abcde	26.75	ab	50.58	d	8.79	defgh
12	5503	30.17	cdef	28.68	cd	3.41	cde	21.58	cd	60.50	abc	8.28	fgh
13	2501	41.22	a	37.19	ab	3.96	abcde	22.50	cd	54.92	cd	8.93	cdefgh
14	75011	25.76	f	24.47	d	3.48	abcde	20.48	cd	59.52	abc	7.93	h
15	5504	32.10	cdef	30.14	abcd	3.24	e	22.13	cd	57.37	abcd	7.91	h
16	5502	29.51	cdef	27.62	cd	3.46	bcde	23.78	abc	52.30	cd	8.08	gh
17	5505	27.45	def	26.23	cd	3.37	de	22.30	cd	55.33	cd	7.16	h
18	Agria (check)	28.58	cdef	25.74	cd	3.62	abcde	21.51	cd	60.22	abc	7.82	h
19	2508	34.21	bcde	32.28	abcd	4.17	abc	23.23	bcd	53.17	cd	8.24	fgh
20	6003	34.65	abc	32.92	abcd	4.19	abc	23.45	abc	64.38	ab	11.96	a
21	3501	29.66	cdef	26.90	cd	4.01	abcd	21.62	cd	58.98	abc	10.01	bcdefg

Table 4. Correlationbetween different traits of potato clones by spearman method

Traits	Total yield	Marketable yield	No. Main stems	Dry matter %	Plant height	Tubers/ plant
Total yield	-	0.954**	0.124 *	0.174*	0.194**	- 0.06ns
Marketableyield	-	-	0.099ns	0.199 **	0.184*	- 0.080ns
No. Main stems	-	-	-	0.005ns	0.117ns	0.018ns
Dry matter	-	-	-	-	- 0.358**	0.463**
Plant height	-	-	-	-	-	- 0.230**
Tubers/ plant	-	-	-	-	-	-

ns,** and * : not significant, significant at 1% and 5% probability level.

Seven potato clones including 6003, 6001, 75013, 7508, 3504, 3505 and 25020 had the most tuber number per plant among the studied clones and the check cultivar. Interestingly, three superior clones in terms of marketable yield were among this group.

In addition to the agronomical traits, a complex set of external quality traits is required for fresh market and processed potatoes. Some potato clones from both hybrid and OP including 2501, 2508, 25020, 6003, 6001, 3503, 3504, 1502, 5503, 8005, 7508, 75013 were detected as suitable clones in external and growth characters including round to oval shape, cream to yellow color and superficial eye. The growth habit of this group was semi-erect to erect. Except for 1502 which was determined as late mature clone with 140-150 days of growth period, the rest were early to mid - late mature potato clones with the ranging of 100- 140 growth period.

The result of correlation between traits in the experiment showed that there is a positive and mostly significant correlation among total, marketable yield and studied traits except for tuber per plant. The trait tuber per plant correlates in negative not only with total and marketable yield (with amount of - 0.06 and - 0.08) but also plant height with the amount of - 0.230.

All traits except for plant height were in positive correlation with the percentage of dry matter. Among the positive traits, it seems that marketable yield dramatically correlate with dry matter in the amount of 0.199 at 1% probability level (P< 1%). On the other hand, the number of main stems didn't have any significant impact on the percentage of dry matter (table 4).

The phenotype of a potato plant is somewhat variable in relation to many traits of interest for potato breeders. The effect of environment on quantitative and qualitative traits such as yield, tuber number, tuber size, dry matter, and processing quality confront challenges that are hard to suppress. Indeed, many quantitative loci have been detected for different traits, but few are usually stable across different environments. In order to get a proper perception of the environmental effect on the traits, it requires testing the breeding potato clones in multiple locations (Schäfer-Pregl et al., 1998). Intercrossing of heterozygous tetraploid clones and commercial cultivars are more common in classical potato breeding (Bradshaw and Mackay, 1994). In this research, advanced potato clones selected from hybrids of commercial cultivars and open pollinated population were evaluated for different traits in three production sites in Iran. The most number of studied clones related to hybrid Kufri Bahar × Concorde and OP population "Khorasan". Nevertheless superior clones were among different hybrids (Ajax × Kufri Jyotii, Kufri Badeshah × Kufri Bahar and Kufri Bahar × Kufri Jyotii) and one OP (Zolushka). In breeding of potato, yield is the main trait that must be considered from early steps.

In addition to the yield, tuber quality and disease resistance are the main focus during cultivar development (Jansky, 2009). Two traits are related to yield in potato including total and marketable yield. Potato breeder usually measure marketable yield and believe that it is more important than total yield. In this study most of the potato clones from both Hybrid and OP, yielded more than check cultivar, Agria. Comparing of total yield among potato clones showed that except three potato clones, all were superior to Agria.

However after subtracting the wasted and tiny tubers from total yield, the means of marketable yield of all studied clones were higher than the check (table 3).

During a breeding program on potato, three superior clones with good quantity and quality traits were determined among eighteen promising potato clones in Ardabil province of Iran (Hassanpanah and Hassanabadi, 2012). In other research, stability of thirteen advanced potato clones for high marketable yield in different environmental condition was studied by GGE Biplot and AMMI models. Among the potato clones, three with high stability performance and good characters to the check cultivars were selected (Hassanpanah and Hassanabadi, 2014).

In potato breeding, the trait main stem is another important character. As a matter of fact, more productivity and yield could be achieved while a plant produce more strong main stems (Cutter, 1978; Meltzer, 1992). Potato plants with more main stems not only make benefit of more photosynthetic capacity but also the stored light photosynthetic compounds in the leaves could be assimilate to the daughter tubers (Moorby, 1970). There was a positive and significant correlation between total yields and number of main stems. The potato clones which yielded more than others and ranked as group A statistically, were regarded among the top eleven clones in number of main stem as well (table 3).

Although a positive correlation exists between the number of main stems and marketable yield, it was not significant. Two potato clones including 1502 and 5504 which were in the group of high marketable yield clones, didn't have main stem as many as the eleven superior clones. Probably having high percentage of tubers in the range of normal size and tolerant to diseases and stresses which cause rotting and necrosis of tubers could compensate the less number of main stems in these potato clones.

Height of those potato clones which produced more total and marketable yield, were in the range of 55 to 65cm. As the table 4 showed plant height correlate with the yield of potato clones. It is deduced that plant height has a good impact on the yield in potato. The results of other research showed that the superior clones usually stand higher with uniformity in growing (Hassanpanah and Hassanabadi, 2014). These characters especially in the beginning of growth stage were prominent for the top potato clones.

One of the breeding traits which have considerable importance in potato processing is dry matter content. This trait must be considered during breeding for determining the suitability of clones for crisps and french-fries. The least amount for potato processing usage is about nineteen percent. The more this amount results in better processing of potato tubers. Consequently, less cooking time, better texture of flesh will result and finally less oil will be used for chips and french-fries (Vander Woude, 1998). Measuring dry matter of potato clones in this study showed that they were more than nineteen percent.

Two clones related to hybrid Ajax ×Kufri Jyotii and one OP from Khorasan population had the highest content of dry matter. Interestingly the two hybrid clones were amongst the superior clones in terms of marketable yield as well. Among different traits in these study only number of tuber per plant didn't have any correlation with total and marketable yield. However, it has a positive and significant correlation with dry matter content. All of top potato clones produced the most tubers per plant were among the superior clones with the highest dry matter content. Most of potato clones which were superior in yield and dry matter have a growth period between 120-140 days and classified as early to mid-late mature potato.

The long period of growth and fresh foliage of potato clones has a great effect on bulking of tubers and increasing in yield. However in the breeding program early to mid-late mature potato clones or late-mature ones that early harvesting of their crops has no impact on their yield or dry matter is recommended specially for off-season cultivation (Silva and Pinto, 2005).

CONCLUSION

Altogether, potato clones including 8005, 6003, 2501, 6001,3503, 3504, 75013, 7508, 2508 with good agronomical traits including high yield or dry matter and suitable external quality traits such as cream or yellow flesh color, round-oval shape, superficial eye and early to mid-maturity were selected and could be used for fresh or industrial consumption.

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