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EFFECTS OF GROWING CONDITIONS ON CROSSING SUCCESS IN DIFFERENT POTATO (*Solanum tuberosum* L.) CROSSES

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ABSTRACT

This study was carried out to determine the effect of growing conditions under different altitudes on seed production in different potato crosses in Tokat Province of Turkey in 2015. Plants were grown and crosses were made in open field or net house in Tokat location (altitude 600 m asl.), open field or net house in Artova location (altitude 1200 m asl.), or controlled polycarbonate greenhouse. Fifteen different crosses were made between 12 parent cultivars. Production of hybrid potato seed was considered "crossing success". Results showed that parent cultivars and cross combinations affected crossing success and no seeds were produced from some combinations while some combinations produced abundant seeds. The highest number of seeds were produced in controlled polycarbonate greenhouse, whereas very low amount of seeds were produced under low altitude (600 m asl.) open field conditions. Polycarbonate greenhouse produced 47.3% of all seeds, while low altitude net house produced 19.8%, high altitude open field produced 15.8%, high altitude net house produced 13.6% and low altitude open field produced 3.5%. It was concluded that for a high crossing success, potato crossing should be made by controlled polycarbonate greenhouse conditions and 23 C^0 day / 17 C^0 night temperatures produced more hybrid seeds.

Keywords: *crossing,crossing success, combination, growing condition.*

INTRODUCTION

Hybridization studies are important for the development of new potato varieties. The success rate in hybridization is influenced by several factors such as day-night temperature difference and the developmental state of plants during pollination period depending on mainly genotype, day length, temperature and altitude (Kurt, 2004; Muthoni *et al.*, 2012; Esendal, 1990). Genotype, day length, temperature are the main factors determining flowering and fruit formation in potato. In addition, there are some other factors affecting flower production and fruit formation such as flowering position plant stem density (Almekinders, 1992), competition between flower and tuber formation, rainfall and irrigation conditions (Jauhnl, 1954), nutrient levels (Bamberg and Hanneman, 1988; Otazu and Amoros, 1991) and the

number of plants (Jauhnl, 1954). Parent characteristics should be known so that a suitable crossbreeding program can be administered.

In recent years, some researchers have implemented several experimental methods to determine parent characteristics. They also determined that the methods developed for hybrid prediction had value appropriate and practical enough to be employed in potato breeding programs as well (Mendoza, 1987; Brown and Caligari, 1989). In cases where hybridization is implemented in potato breeding, it may not always be possible to obtain fruit or seeds depending on various reasons. This can stem from such factors as ploidy differences of parents, infertility, divergence or flowering. Flowering in potato is particularly important in parent lines to be used in breeding. In order for flowering to occur in potato, a temperate climate plant, a cool climate or longer photoperiod is needed. When potato is grown in high altitudes in long summer days, flowering occurs easily under natural conditions (Gupta *et al.,* 2004). Similarly, Gopal (1994) reported that more flowering and fruit formation occurred in tropical and subtropical plants grown in areas with high altitudes (>1500 m asl.).

In order to be more successful in breeding process, more flower formation and longer flowering period is favored. In addition to the above mentioned procedures to ensure flowering in potato plant, gibberellic acid (GA_3) can be administered to the plant. This application can create the effect of long day conditions (Esendal, 1990). Nitrogen, applied in high doses and at certain periods more than recommended for tuber production, increases flowering, delays maturing of the plant and lengthens the fruit development period (Pallais, 1985). Light intensity and light exposure time (day length) are effective in fruit formation and developing more seeds within the fruits following hybridization in potato. 14-18 hours of day time and temperatures of 15-20°C are suitable for flowering and fruit formation (Clarke and Lombard, 1939; Bodlander, 1963; Almekinders, 1992).

Turner and Ewing (1988) studied the effect of some environmental factors on falling of flower bods in some potato clones and found that photoperiods longer than 12 hours lowered the fall of flower buds compared to shorter photoperiods and night temperatures higher than 20°C lowered more than 10°C did. Thus, longer photoperiods and higher night temperatures promoted flower development while lower light intensity (50% of day light) suppressedit.

Weber *et al.* (2012), reported that no seeds were obtained in some crossing studies of potato due to various factors including pollen-pistil incompatibility, where some parents are incompatible with each other and no seeds were produced in reciprocal crosses of some parents. They reported that F_1 hybrids produced no seeds when used as female in crosses with wild potatoes whereas no seeds were obtained when used as male. In addition to pollen-pistil incompatibility, obstacles due to embryo and cytoplasmic male sterility were also mentioned to be the causes of problem to produce seeds in potato crossings (Camadro and Peloquin, 1981; Erazzu *et al*., 1999; Ispizua *et al*., 1999; Camadro *et al*., 2004).

The aim of this study isto determine the effect of growing conditions under different altitudes on hybrid seed production and crossing success in different potato crosses in Tokat Province of Turkey.

MATERIALS AND METHODS

This study was carried out in 2015 under Tokat Artova conditions. 15 Cross combinations (A2/11 x T6/28, A3/110 x A2/11, A10/15 x A3/223, A7/12 x A10/15, A8/34 x A13/1, T4/4 x T6/28, A2/11 x Melody, A7/12 x Van Gogh, A3/223 x Megusta, Başçiftlik Beyazı x A13/1, Başçiftlik Beyazı x Megusta, Başçiftlik Beyazı x Van Gogh, Aleddiyan Sarısı x Megusta, Aleddiyan Sarısı x A2/11 and Aleddiyan Sarısı x T6/28) were made in polycarbonate greenhouse, net house or open field in Tokat Kazova (altitude 600 m asl.), and open field and net house in Tokat Artova (altitude 1200 m asl). Crossings in polycarbonate greenhouse in Tokat Kazova were carried out during winter and summer of 2015, while other crossings were carried out during 2015 summer.

Growing Parent Plants

Planting was made in different dates to get flowers from different genotypes at the same time and to get more seeds. Planting dates were as follows; Tokat net house: April 21st,May 13rd,June 24th, Tokat open field; April 30th, June 3rd, Tokat Artova open field; April 4th, May 21st, June 17th, Tokat Artova net house; April 18th, June 10th. For plantings in greenhouse, 33x26 cm pots containing 1/3 torf, soil and perlit each were used. Planting open fields were made in 100x70 cm hills. Three plant were grown for each parent in each planting period. Plantings for 2015 winter period in polycarbonate greenhouse were started in November 11th and December 3rd, and plantings for 2015 summer were continued until February 27th, May 5th and July 1st. After the emergence, plants were monitored and necessary weeding, watering, fertilization, side branch removing, stolon cutting and pesticide application were performed.

Crossing and Production of Hybrid Seeds

Parents were monitored carefully after the formation of flower buds. Emasculation and crossing were made according to Poehlman and Sleeper (1995). Before the flowers opened, petals were opened carefully without stigma and 5 anthers removed without damaging sacs using fine-tip forceps early in the morning. Other flowers were removed to make emasculation easier and to prevent possible contamination. No isolation of emasculated stigma was applied to prevent damage to female organ (Fehr and Hadley, 1980). Pollinaton was made by applicaiton of polen to the stigma of female plant. Polen was obtained from pollen sacs of mature male plants. If the pollen was not ready, pollination was made the following day. Pollination were started after flowering on June 15th 2016 in Tokat net house, on July 1st 2015 in Tokat open field, on July 3rd in Artova open field on july 15th in Artova net house and on February 10th in polycarbonate greenhouse. In order to promote plant growth, flowering and to increase the succes of crossing, long day

conditions were created using artifical light in greenhouse conditions and temperature of greenhouses were adjusted to 16°C night/22°C day using temperature control mechanisms. When fertilization occured in pollinated flowers, swelling was observed in ovarium about 5 days after the pollination. Mini berries were seen after another 3-5 days and remnant of petals in the upper part fell. Berrieswere prevented from falling and getting last by special net sacs prepared for this purpose. Developing crossed berriesgot larger as their growth prolonged. Seeds in berrieswhich completed the physiological development were separeted from berry in a container filled with water. Findings were subjected to correlation analysis using SPSS-20 statistical package programme.

RESULTS AND DISCUSSIONS

Seed set success of different potato combinations was different. Some combinations produced many berries and seeds while some produced none. Number of crosses madefor each combinations varied between 36 and 415 and seeds were produced from all combinations except for three (3, 4 and 15). The highest berry ratio was obtained from combinations 5, 10, 11 and 12. Number of seeds per berry was highest for combinations 2,5 and 9, (Table 1). The highest number of seeds were produced by combinations 5, which had 37.5 of berry set and a high seed set per pot. Higher berry set and seed production in combinations 10, 11 and 12 shows the good combination ability of parents in these combinations.

Table 1. Number of crosses made, seed set ratio and number of produced seeds

No	Combinations	Number of crosses	Berry set ratio (%)	Number of seeds produced	Number of seeds per berry
1	A2/11 X T6/28	71	1.4	26	26
2	A3/110 X A2/11	180	17.7	3014	94.1
3	A3/110 X A3/223	392	-	-	-
4	A7/12 X A3/110	415	-	-	-
5	A8/34 X A13/1	165	37.5	6711	108.2
6	T4/4 X T6/28	114	17.5	195	97.5
7	A2/11 X Melody	65	12.3	682	85.25
8	A7/12 X Van Gogh	264	7.1	994	52.3
9	A3/223 X Megusta	189	1.5	586	195.3
10	Başçiftlik B. X A13/1	251	49.8	7651	61.2
11	Başçiftlik B.X Megusta	138	44.2	942	15.4
12	Başçiftlik B. X Van Gogh	301	38.8	2634	22.5
13	Aleddiyan S. X Megusta	36	22.2	295	36.8
14	Aleddiyan S. X A2//11	107	19.6	939	44.7

15	Aleddiyan S. X T6/28	37	-	-	-
Total / avarage		2725	17.8	24669	53.7

Relations between number of crosses made and numbers of hybrid berries and seeds were given in Table 2. Based on the results, there were negative correlations between combinations and number of crosses made, number of hybrid seeds and berries, and a positive correlation between combinations and berry set ratio.

Table 2. Correlations between number of crosses, berry set ratio and number of hybrid seeds according to combinations

	Combinations	Number of crosses made	Berry set ratio (%)	Number of hybrid seeds
Number of crosses made	-,341*			
Berry set ratio (%)	,315*	-,046		
Number of hybrid seeds	-,020	,137	,731**	
Seeds/berries	-,133	-,200	,030	,258

CV%: 1.6,*p<0,05, **p<0,01

A total of 24,669 hybrid seeds were produced from five different conditions (Table 3). The highest number of seeds were produced from polycarbonate greenhouse. It was followed by net house in Tokat (4899 seeds) and high elevation areas. Number of seeds produced varied from 26 to 7651 in different growing conditions. Combination 2, 5, 10 and 12 produced more seeds than others. Combination 10 produced higher number of seeds in all growing conditions. Berry set ratio was highest in Artova open field condition but the highest number of seeds were produced in controlled polycarbonate greenhouse because of higher number of crosses which could be made in the latter condition. Although the success was low in lower altitude Tokat open field conditions, here net house of preferably controlled polycarbonate greenhouse gave better results. Seed production was better in open field conditions of high elevation Artova, where net house also gave satisfactory results.

Table 3. Number of hybrid seeds in different growing conditions

Combinations	Tokat open field	Tokat net house	Artova open field	Artova net house	Polycarbonate greenhouse	Total
1. A2/11 x T6/28					26	26
2. A3/110 x A2/11					3014	3014
3. A3/110 x A3/223						-
4. A7/12 x A3/110						-
5. A8/34 x A13/1		3378	537	428	2368	6711
6. T4/4 xT6/28					195	195
7. A2/11 x Melody	370		112	160	40	682
8. A7/12 x Vangogh		194			800	994
9. A3/223 x Megusta				489	97	586
10. Başçiftlik Beyazı x A13/1	418	1246	2243	1503	2241	7651
11. Başçiftlik Beyazı x Megusta		2	-	225	715	942
12. Başçiftlik Beyazı x Van Gogh	85	79	270	471	1729	2634
13. Aleddiyan Sarısı x Megusta					295	295
14. Aleddiyan Sarısı x A2/11			717	72	150	939
15. Aleddiyan Sarısı x T6 /28						-
Total	873	4899	3879	3348	11.670	24.669

Table 4. Number of berries and seeds produced in different growth conditions

Conditions	Number of crossed flower	Number of hybrid berry	Berry set ratio (%)	Number of hybrid seed	Hybrid seed ratio (%)	Seeds /berry
Tokat open field	89	24	26.9	873	3.5	36.3
Tokat net house	410	82	20	4899	19.8	59.7
Artova open field	306	89	29	3879	15.8	43.5
Artova net house	267	60	22.4	3348	13.6	55.8
Polycarbonate greenhouse	1653	204	12.3	11670	47.3	57.2
Total / average	2725	459	17.8	24669		53.7

Polycarbonate greenhouse where the highest number of flowers were crossed (1653) produced higher number of hybrid seeds (11670) (Table 4). Flower development was affected by growing medium. Controlled conditions or higher elevation open fields produced more flowers, and consequently more berries and seeds. Berry set ratio, another parameter affecting crossing success, was high in open field conditions (26.9 and 29.0% in Tokat and Artova, respectively). However, number of crosses made was low in open field conditions (Table 4). The results showed that number of flowers crossed and number of seeds produced were significantly and positively correlated (Table 5).

Table 5. Correlations between number of flowers crossed, number of hybrid berries, seeds sets /berry based on combinations

	Combination	Number of flowers crossed	Number of hybrid berries	Berry set ratio	Number of hybrid seeds	Hybrid seed ratio
Number of flowers crossed	,749**					
Number of hybrid berries	,790**	,974**				
Berry set ratio	-,656**	-,903**	-,846**			
Number of hybrid seeds	,783**	,982**	,991**	-,907**		
Hybrid seed ratio	,784**	,982**	,990**	-,906**	,998**	
Number of seeds /berry	,587*	0,487	,529*	-,717**	,607*	,601*

CV%:0.4, *p<0,05, **p<0,01

It was found that especially combinations, elevation where the crossing was made and growing conditions affected the success of crosing in potato. The fact that some combinations produced no seeds while others produced many hybrid seeds clearly showed the importance of compatibility of parents in each crossing. With this respect, Weber *et al.* (2012), reported that no seeds were produced when pollen and pistil were incompatible. Erazzu´*et al.* (1999) and Camadro *et al.* (2004), on the other hand, reported that in addition to pollen – pistil incompatibility obstacles due to embriyo and cytoplasmicmale sterility negatively affected seed set in crossing studies of potato.

Relationship between number of flowers and hybrid seeds and pots were significant and positive. This fact could be due to the fact that environmental conditions and especially long day conditions and temperate conditions in which temperature was not very high led to the formation of many flowers. Similarly, Esendal (1990) and Muthon *et al.* (2012), mentioned that longer day conditions promoted flower development in potato and produced more branches and flowers. Higher number of flowers increase number of crossed flowers. However, in addition to day length, temperature and light intensity are also known to be important in prevention of berry loss after crossing. Similarly, Gopal (1994), showed that loss of flower buds and pots produced were lower in places of higher elevation. Turner and Ewing (1988), on the other hand, mentioned that bud loss was higher and berry set was lower in conditions where day length and light intensitiy were smaller. The same authors reported that 20 °C suppressed bud and berry loss more compared to 10°C and that temperate conditions were more favorable compared to higher or lower temperature conditions.

CONCLUSION

The present study revealed that compatibility of parent, elevation and growth conditions affected the success of potato crosing through temperature and day length and that long day conditions facilitated by conrotolled growing conditions and 23°C day/17°C night temperatures produced more hybrid seeds. In addition, it was found that 1200 m elevation open field conditions and net house conditions resulted in higher crossing success compared to low altitude areas.If it is crossing in potato, high altitude must be selected. Furthermore, greenhouse should be used to make regularhybridization.

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