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Identification of climate resilient, short duration and high yielding advance potato (*Solanum tuberosum* L.) strains

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Abstract

Potato can address the threat to food security by playing an important role to bridge up the alarming disparity between population growth rate and food demand due to the shortage of staple cereal grain. In Pakistan, climate change is adversely impacting agriculture crops rapidly. Potato, as a temperate crop, is more affected from the temperature fluctuations. So, there is a dire need to evolve early bulking varieties to cope with the changing climate. Present study was conducted to evaluatethe advance potato strains (FD 73-49, FD 73-44, FD 76-67& FD 77-4) in this respect against two checks (Sadaf & SH-5) at Potato research institute, Sahiwal. Split plot design with four treatments (harvesting after 70 days, 90 days, 110 days & 130 days of sowing) and three replications for two agricultural seasons was followed. The results showed that different strains/varieties showed marked differences for marketable & total yield on different harvesting dates. Numberof undersized tubers (<35mm), medium sized tubers (35-55mm) and large size tubers (> 55 mm) also showed great differences with different harvesting dates. The strain/variety FD 73-49 showed highest marketable yield (13.2t/ha to 16.1t/ha) & (13.4 to 34.5t/ha) during the agriculture season 2015-16 and 2016-17 respectively and proved to be a very early strain/variety, also FD 73-44 depicted results as very early bulking strain which showed marketable yield less than FD 73-49 but higher than rest of the strains/varieties. Sadaf and SH-5 showed higher marketable yields than FD 76-67& FD 77-4 and falls in early group while later two verities in medium early group. So, results depicted that FD 73-49 showed best results in short time period suggesting this early bulking variety which could help breeders and farmers to avoid the effect of changing climate especially in Pakistan with wider adaptability and higher yields.

Keywords: Early bulking, tubers, strains, climate change, temperate, adaptability

Introduction

Food demand is increasing rapidly with the day by day population increase. Such disparity between alarming population growth & supply of food caused the shortage of cereals due to less global acreage and yield for which potato has become an alternative important source of food to fulfill the dietary needs of people around the world. This crop has the potential to bridge up the gap between demand and supply of food and addresses the challenges of food security. Potato (*Solanum tuberosum* L.) belongs to the Solanaceae family and is one of the most important edible vegetable, mostly cultivated in moderate climate (Ross, 1979; Grun, 1990). Potato stands at fourth position after wheat, rice and maize among food crops in the world (Hamm and Baron, 1999). In Pakistan Potato (*Solanum tuberosum* L.) is very important commercial crop and its grown in three different seasons i.e., autumn and spring in plains while summer in the hilly areas due to great variation in temperatures and altitudes.

Potato is a good source of fiber, low in cholesterol, contains various vitamins & minerals as well as a range of phytochemical like natural phenols and carotenoids. Edible potato portion of 100 g contain 78 kcal of energy, 2.4g protein, 79.9g water, 36mg calcium, 16.8g carbohydrates, phosphorus 49mg, 31mg ascorbic acid, 2.2mg niacin, 1.1mg iron, 0.12mg thiamine and 0.06mg riboflavin (Tamm, 2007). Vitamin C is present in the skin of Potato which prevents scurvy disease in children (Woolfe and Poates, 1987). It is a healthy nutritional food for adults as potato contains protein low in sulphur containing amino acids and high in lysine (Bouis and Scott, 1996). Tubers of potato crop can be employed in the production of spirits, starch and industrial alcohol (Mujaya and Mereki, 2010). Potatoes are mostly consumed by using them as boiled, roasted, eating fried and in raw form. Potato cultivation in the sub-content is reported to have been introduced in 16th century. In Pakistan potatoes are grown on an area of 179.3 thousand hectares with production of

3849.5thousand tones & average yield of 21.5 t/ha (Economic Survey of Pakistan, 2016-17).

Potato production has been increased 160 times from 24 thousand tons to 3849.5 thousand tons from 1947 to 2016-17. Although, the average yield of potato in Pakistan is higher than the world average, however it is far low as compared to the developed potato producing countries i.e New Zealand, Netherland, France, Germany etc. One of the constraints in this regard is climate change, which through rising temperatures, enhanced atmospheric CO2, changing patterns of precipitation and more extreme weather events likely to affect the potato production (Jatav*et al*., 2017).

Pakistan is at 7th position which is most effecting from climate change where Potato is a temperate crop and higher day temperatures causes some areas to less suitable for potato production due to lower tuber yields and its quality. Tuber growth and yield is severely reduced by temperature fluctuations outside 5-30 °C (Jatav*et al*., 2017). Temperatures above 30 °C can have several negative impacts on potato production like: slowing tuber growth and initiation, less partitioning of starch to the tubers, physiological damage to tubers (e.g. brown spots), shortened/non-existent tuber dormancy, making tubers sprout too early (Midmore, 1990).

These effects can reduce crop yield and the number and weight of tubers. So, the need of hour is to produce early maturing varieties of potato with high tuber yield so that the negative impacts of high temperature can be minimized. Early maturity depends on the rate and duration of tuber bulking which determines the yield in the potato crop. Tuber bulking results from two basic processes, tuber initiation and tuber growth. Timing and duration depend upon geographic location, environmental factors, and cultivars. Environmental conditions affecting tuber initiation include planting date, early season temperature, nutrition and water management, and weather extremes such as hot climate, hail or frost (Mihovilovich*et al*., 2014) Sensitivity to environmental conditions varies markedly between genotypes (Brown, 2007). Usually maturation phase follows tuber growth, which is characterized by leaf area decline and a slow rate of tuber growth. This phase may not occur in the field when a medium or long season cultivar is grown in a short production season.

Therefore, present research is conducted to evaluate different strains of potato for early bulking, high marketable yield. This research will guide researcher to cope with the changing climate, Global food security & supply driven demand of potato in Pakistan by developing early maturing varieties.

Materials and Methods

This research was planned out to identify & examine the best early maturing strains of Potato with high marketable yields and better quality in the Punjab province of Pakistan during the year 2015-16 & 2016-17. The experiment site is located in the division of Sahiwal with the climatic conditions Fig (1) & Fig. 2 respectively.

Total 04 advance potato strains viz., FD 73-49, FD 73-44, FD 76-67, FD 77-4 were evaluated along with two standard entries i.e. "Sadaf" and "SH-5" for their early bulking potential at Potato Research Institute, Sahiwal. The material was sown keeping 20 cm plant to plant and 75 cm row to row distances. The plot size was kept 7.0 m x 0.75 m. The trial was laid out according to the split plot design with four treatments (harvesting after 70 days, 90 days, 110 days & 130 days) and three replications. The treatments were placed in major plots whereas varieties were placed in sub plots to check the earlybulking potential of advanced strains. Standardized agronomic practices and plant protection practices like weed, disease and pest control were adopted. Data regarding emergence, tuber grades, total yield & marketable yield were recorded. Data were analyzed for variances (Steel et al. 1997). Means separation was conducted by the LSD test at 0.05 level of probability.

Results and Discussion

Fig. 1 shows the tuber development from first harvest (T1) to final harvest during the agricultural season 2015-16. The strain/variety FD 73-49 & FD 73-44 showed undersized tubers of 40.3% & 37.3% during time harvest 1 (T1) and maximum medium size tubers of 74.5% & 75.4% during time harvest 2 (T2) & 4 (T4) respectively. The variety FD 77-4 has highest 44.5 % undersized tubers during time harvest 3 (T3) while 76.7 % medium sized tubers (35-55 or above) followed by variety/line FD76-67 having highest undersize tubers of 72.2 % during time harvest 3 (T3) while 78.5 % maximum medium size tubers. The variety SH-5 &Sadaf has undersized tubers of 56.5 % & 78.9% while maximum medium sized tubers of 61.8 % & 84.1 % respectively. Torres (1979) observed that late planting and early harvesting always produced higher percentage of small sized tubers

Fig. 2 shows the tuber development from first harvest (T1) to final harvest during the agricultural season 2016-17. The strain /variety FD 73-49 showed undersized tubers 40.7 % during time harvest 1 (T1) and maximum medium sized tubers of 74.3 % during time harvest 2 (T2). The strain / variety FD 73-44 & Sadaf showed undersized tubers

37.7 % & 78.7 % during time harvest 1 (T1) and maximum medium sized tubers 75.4 % & 84.1 % during time harvest 4(T4) respectively. FD 77-4 & FD 76-67 showed highest undersize tubers of 44.5 % & 72.2 % during time harvest 3 (T3) while maximum medium sized tubers of 76.7 % & 78.5 % during time harvest 2 (T2) respectively. Studies also confirm that potato tuber yield increased with late harvesting (Workman and Harrison, 1982).

Marketable Yield responses of different Potato early bulking Strains

During the agriculture season 2015-16 the strain FD73-49 shows highest marketable yield (13.2 to 33.1 t/ha) from time harvest 1 (T1) to final harvest followed by FD 73-44 which showed more marketable yield ranging from 13.7 t/ha to 28.2 t/ha from time harvest 1 (T1) to final harvest than rest of the varieties (Table.1). These two varieties are very early maturing than rest of the varieties. Sadaf& SH-5 proved to be early varieties with marketable yield (5.8 t/ha 25.9 t/ha & 10.4 to 19.0 t/ha respectively) from time harvest 1 (T1) to final harvest. Lowest marketable yield ranged from 4.0 t/ha to 11.7 t/ha by the variety FD 77-4 which indicates that this variety is late maturing. (Schliephake & Trautz, 2014) also studied different varieties of Potato for early bulking supporting these studies.

During the agriculture season 2016-17 again the variety FD73-49 showed highest marketable yield (13.5 t/ha to 34.4 t/ha) from time harvest 1 (T1) to final harvest (Table. 2). FD 73-44 also resulted with 2nd highest marketable yield (13.3 t/ha to 29.5 t/ha). Early varieties Sadaf& SH-5 showed yield (11.2 t/ha to 28.1 t/ha & 10.3 t/ha to 19.9 t/ha) from time harvest 1 (T1) to final harvest respectively which shows yield increase than previous years yield of these varieties. The lowest marketable yield (3.3 t/ha to 12.5 t/ha) during this year showed by the variety FD 77-4from time harvest 1 (T1) to final harvest showing that this variety is late maturing as resulted in previous year results. (Mihovilovich *et al*., 2014) also studied Potato strains for different harvesting times supporting the current studies.

Interaction effects of different Potato varieties for Marketable and total yield against different harvesting times

The mean yield responses of different potato strains/varieties against different harvesting dates are presented in Table3 & 4 for the agriculture season 2015-16 &2016-17 respectively. During the agriculture season 2015-16 the variety FD 73-49 showed highest marketable as well as total yield from time harvest 1(T1) to final harvest which proved this strain /variety is very early bulking. Lowest Yield (5.9 t/ha) showed by FD 77-4 during harvesting (T1) to final harvest (T4) suggesting this variety is late maturing as compared to other varieties. The mean marketable yield and total yield during time harvest 1 (T1) remained 9.5 & 12.6 t/ha respectively. Time harvest 2 (T2) showed that the mean marketable yield remained 15.3 t/ha & total yield resulted in 17.0 t/ha. The mean marketable and total yield during time harvest 3 (T3) & final harvest remained 17.3to 20.6 t/ha & 21.7 & 23.4 t/ha respectively. Robert *et al*. (1990) reported that delay in harvesting results in increased number of tubers per plant.

The interaction effects of different Potato early bulking strains/varieties for marketable and total yield against harvesting times are also depicted in the fig.3 which showed that two varieties FD 73-49 & FD 73-44 exhibiting higher yields than other varieties during all harvesting times and could be used as early bulking strains. According to Hassanpanah *et al*. (2009), the maximum total and marketable tuber yield and marketable tuber number per plant were affected by harvesting dates.

Conclusion

The strain/variety FD 73-49 proved to be a very early bulking with highest yield 16.1 t/ha to 35.4 t/ha during 2015-16 &21.3t/ha to 39.1t/ha from first harvest (T1) to final harvest during 2016-17 while the strain FD 73-44 bears out as early variety with yield of 16.0 t/ha to 29.6 t/ha during 2015-16 &19.1t/ha to 28.9t/ha during 2016-17 from first to final harvest time which could help to cope with the changing climate scenario and in short period high yield could be obtained by cultivating these varieties.

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Table 1. Marketable yield depending upon different harvest times for the year 2015-16

Variety	Maturity group	T1 (70 days)	T2 (90 days)	T3 (110 days)	Final (130 days)
		t/ha	t/ha	t/ha	t/ha
FD 73-49	**Very early**	13.2	23.3	27.2	33.1
FD 73-44		13.7	20.0	25.3	28.2
Sadaf	**Early**	5.8	15.1	19.7	25.9
SH-5		10.4	11.7	16.3	19.0
FD 76-67	**Medium early**	10.0	15.3	7.0	12.0
FD 77-4		4.0	6.6	8.5	11.7

(Significance level (p=0.05)

Table 2. Marketable yield depending upon different harvest times for the year 2016-17

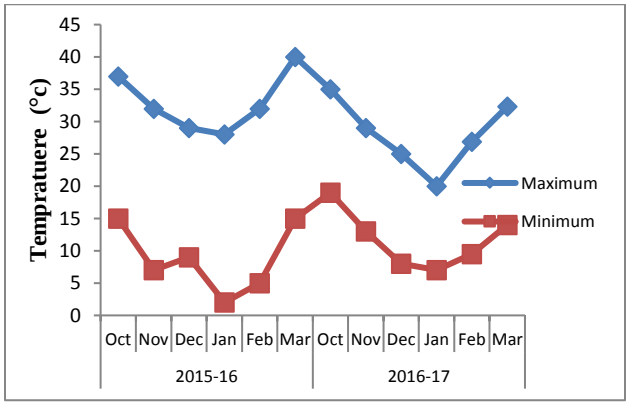
Variety	Maturity group	T1 (70 days)	T2 (90 days)	T3 (110 days)	Final (130 days)
		t/ha	t/ha	t/ha	t/ha
FD 73-49	**Very early**	13.5	23.8	28.3	34.4
FD 73-44		13.3	20.0	26.2	29.5
Sadaf	**Early**	11.2	16.1	19.7	28.1
SH-5		10.3	16.2	17.3	19.9
FD 76-67	**Medium early**	10.0	6.7	8.8	12.5
FD 77-4		3.3	12.2	7.4	12.5

(Significance level (p=0.05)

Table.3 Interaction of marketable and total yield of different Potato strains against different harvesting dates during the year 2015-16

Treatments	Varieties	Marketable Yield (t/ha)	Total Yield (t/ha)
T1= Harvesting after 70 days	FD 73-49	13.2	16.1
	FD 73-44	13.7	16.0
	Sadaf	5.8	13.6
	SH-5	10.4	12.7
	FD 76-67	10.0	11.2
	FD 77-4	4.0	5.9
Mean		**9.5**	**12.6**
T2= Harvesting after 90 days	FD 73-49	23.3	24.7
	FD 73-44	20.0	20.8
	SH-5	15.1	16.8
	Sadaf	11.7	16.5
	FD 76-67	15.3	16.3
	FD 77-4	6.6	7.1
Mean		**15.3**	**17.0**
T3= Harvesting after 110 days	FD 73-49	27.2	30.6
	FD 73-44	25.3	27.8
	FD 76-67	19.7	21.5
	SH-5	16.3	19.5
	Sadaf	7.0	14.3
	FD 77-4	8.5	10.0
Mean		**17.3**	**20.6**
T4= Harvesting after 130 days	FD 73-49	33.1	35.4
	FD 73-44	28.2	29.6
	FD 76-67	25.9	26.5
	SH-5	19.0	20.6
	Sadaf	12.0	15.8
	FD 77-4	11.7	12.2
Mean		**21.7**	**23.4**
	LSD 5%	**4.13**	**3.97**

** Significant (α=0.05)* *** Highly significant (α=0.01)*



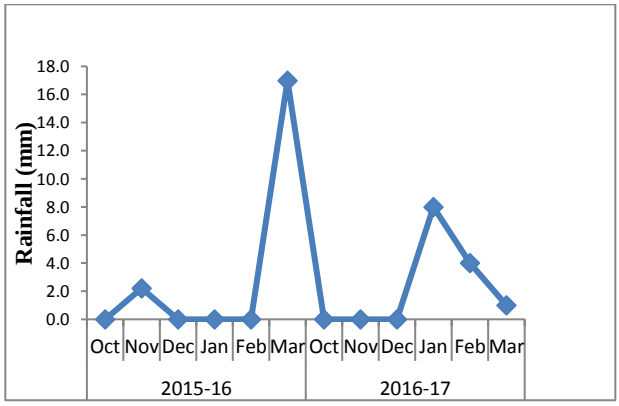


Table.4 Interaction of marketable and total yield of different Potato strains against different harvesting dates during the year 2016-17

Treatments	Varieties	Marketable Yield (t/ha)	Total Yield (t/ha)
T1= Harvesting after 70 days	FD 73-49	13.5	21.3
	FD 73-44	13.3	19.1
	Sadaf	11.2	11.2
	SH-5	10.3	13.1
	FD 76-67	10.0	7.7
	FD 77-4	3.3	15.9
Mean		**10.2**	**14.7**
T2= Harvesting after 90 days	FD 73-49	23.8	22.2
	FD 73-44	20.0	19.5
	SH-5	16.1	16.6
	Sadaf	16.2	16.2
	FD 76-67	6.7	7.0
	FD 77-4	12.2	17.4
Mean		**15.8**	**16.4**
T3= Harvesting after 110 days	FD 73-49	28.3	33.5
	FD 73-44	26.2	29.1
	FD 76-67	19.7	22.2
	SH-5	17.3	23.4
	Sadaf	8.8	11.7
	FD 77-4	7.4	16.9
Mean		**17.9**	**22.8**
T4= Harvesting after 130 days	FD 73-49	34.4	39.1
	FD 73-44	29.5	28.9
	FD 76-67	28.1	28.7
	SH-5	19.9	21.6
	Sadaf	12.5	13.1
	FD 77-4	12.5	16.7
Mean		**22.8**	**24.6**
	LSD 5%	**4.13**	**3.97**

** Significant (α=0.05)* *** Highly significant (α=0.01*

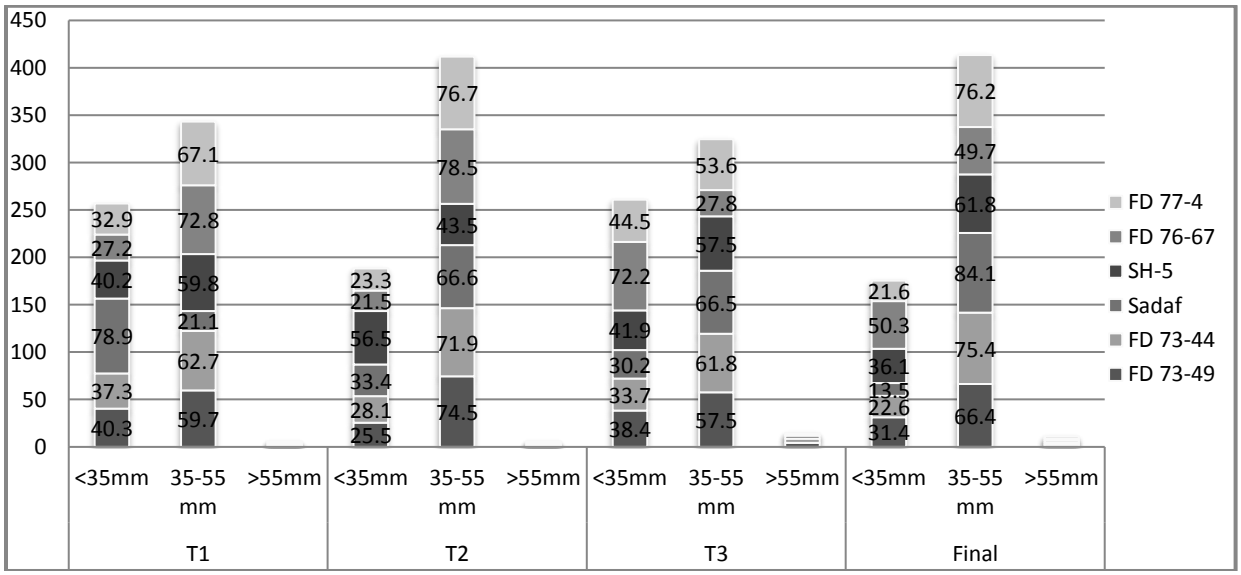


Fig.1. Tuber development from harvest T1 to final harvest during the agriculture season 2015-16

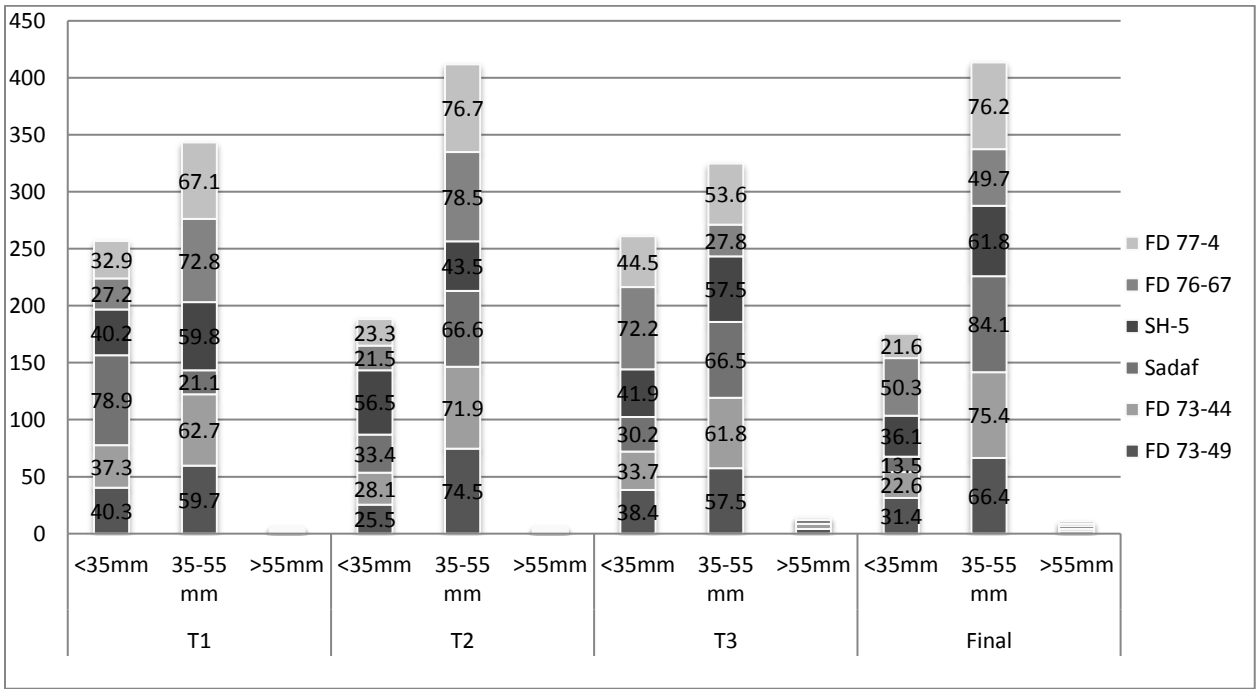


Fig.2. Tuber development from harvest T1 to final harvest during the agriculture season 2016-17

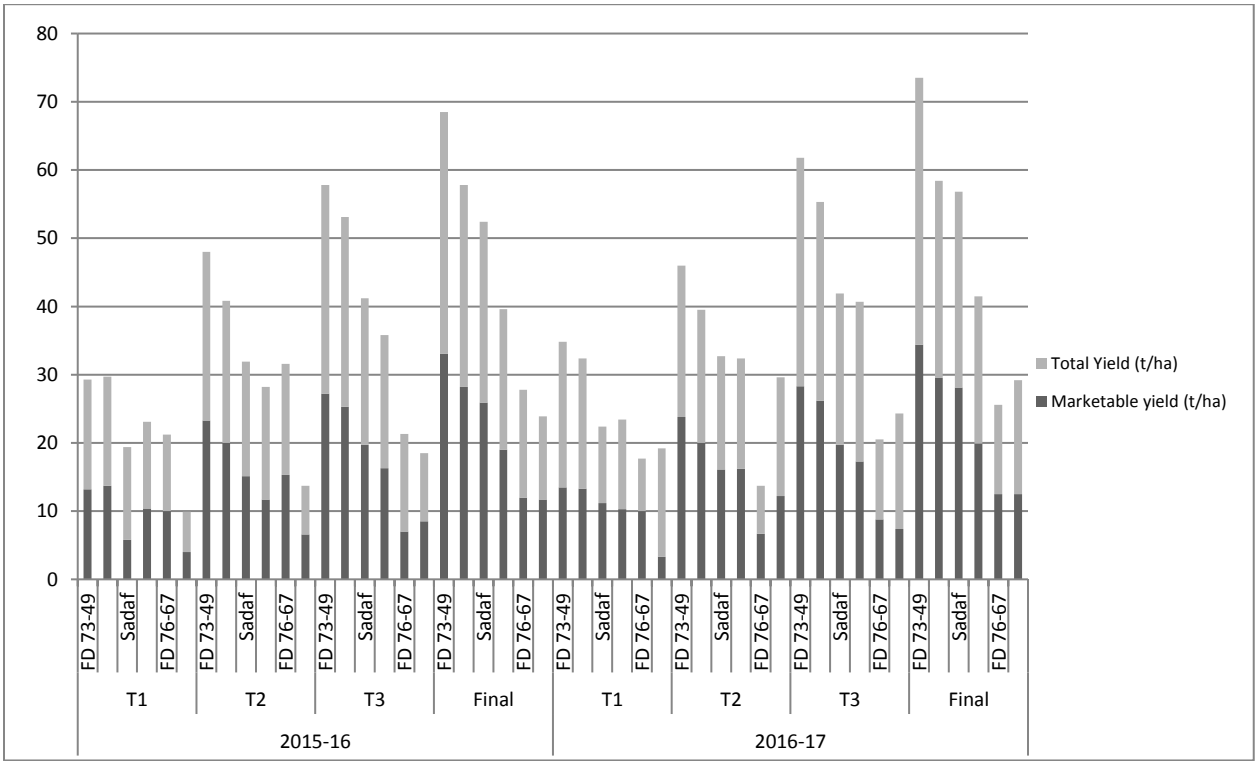


Fig. 3 Interaction of different early bulking Potato strains/varieties against different harvesting times