International Journal of Biology Research
ISSN: 2455-6548
Impact Factor: RJIF 5.22
www.biologyjournal.in
Volume 3; Issue 3; July 2018; Page No. 09-17

Impacts of breeding research in sugarcane in Punjab (2000-01 to 2016-17)

Muhammad Ijaz Tabassum[1*], Mohammad Ishaq Javed[2], Muhammad Ashfaq Nadeem[3], Naeem Ahmad[4], Iftkhar Nabi[5], Muhammad Shuaib Kamran[6]

[1, 3, 4] Sugarcane Research Institute, Faisalabad, Pakistan

[2, 5, 6] Agri. Economic section, Ayub Agricultural research Institute, Faisalabad, Pakistan

Abstract
Ayub Agricultural Research Institute (AARI) is the premier research organization of the country. It has been at the forefront in developing sugarcane production in the country. Sugarcane varieties developed by AARI's Research System have been widely appreciated and opted by the sugarcane growers of the country. During 2016-17, sugarcane varieties developed by AARI's research system were planted over 92% sugarcane area of Punjab. The main objectives of the study are to document the spread and adoption of AARI's sugarcane varieties and assess the impacts of AARI's sugarcane varieties in Punjab from 2000-01 to 2016-17.The results of the study revealed that sugarcane breeding research has generated enormous benefits during the whole study period. During 2016-17, economic impact of sugarcane breeding research of Ayub Agricultural Research Institute, Faisalabad was estimated at Rupees 38 billion. Economic benefits averaged Rs. 15.85 billion per year during the whole study period.

Keywords: AARI, varieties, breeding research, economic impact

1. Introduction

Sugarcane (*Saccharum officinarum* L) is an important cash crop of many agricultural countries including Pakistan. It is a versatile crop and a rich source of food, fiber, fuels, chemicals and fertilizers. Every part of sugarcane plant from top to bottom is utilized in one form or the other, directly by mankind or the industry. The crop is of immense economic importance for the prosperity of the people. Its importance can be judged from the fact that sugarcane is cultivated in nearly 115 countries of the world and has attained importance due to its status of a cash crop for farmers, a sweetener for consumers, strong base for agro-industrial chemicals with value added products and renewable energy resources. Sugarcane, though a tropical plant, is cultivated in both the tropical and sub-tropical regions. It is grown in countries within latitudes 37º N and 32º S of equator. Sugarcane is also being grown in extreme climate and in areas most unlikely for its production. Africa and Asia have relatively higher proportion of sugarcane grown in 25^0 -35^0 latitudes, while sugarcane area in America and Oceania mostly fall in latitude ranges of 20^0-25^0. This wide spread cultivation is due to the morphological and genetic changes in sugarcane that occurred because of inter-breeding among various varieties. Europe has negligible area under sugarcane. According to FAO (2016) [11], Americas produces 52.3% (Table 1, Figure 1)) of the world sugarcane followed by Asia (39.9%), African (5.7%) and Oceania (2.2%). Enhancement in area and production is observed in horizontally as well as vertically during the last one and a half decade in the world. Area multiplied from 19.59 mh to 26.77 mh during the mentioned period. Similarly, production increased from 1258 mt to 1891 mt during the same span of time (Table 2). Brazil, India, China, Thailand, Pakistan, Mexico, Colombia and Indonesia were the main sugarcane producing countries. Brazil occupied1st position in sugarcane production with 769 million tons while India at 2nd position with 348 million tons followed by China with 123 million tons, Thailand with 87 million tons, Pakistan with 65 million tons, Mexico with 56 million tons, Colombia with 37 million tons, Indonesia with 34 million tons, Guatemala with 34 million tons and United States with 30 million tons (Table 3)

Being an important and high value cash crop of Pakistan, sugarcane plays an important role in the uplift of socioeconomic conditions of the sugarcane growing families. It accounts for 3.4 % in agricultures value addition and 0.7 % in overall GDP of Pakistan (GOP, 2017). It has been growing in Pakistan from the time immemorial and is attributed to the mighty river Indus and its tributaries. The region known as Indus civilization historically had the knowledge of sugarcane production and the extraction of brown sugar cakes. In Pakistan, sugarcane cultivation is confined in parts of coastal area and plains of river Indus and adjoining rivers in Sindh, Punjab and KPK.

At the time of independence, sugarcane was cultivated on 189.4 thousand hectares which increased to 1217 thousand hectares in 2016-17, showing six fold increase in sugarcane cultivation. In 1947, total sugarcane production in the country was 5.5 million tons with an average yield of 29.19 tons/hectare. During 2016-17, total sugarcane production was recorded 73.60 million tons with an average yield of 60.40 tons/hectare (Table 4). Simultaneously sugar industry has also developed at fast rate in the country. At the time of independence, there were only two sugar mills in Pakistan. Today there are 90 sugar mills operating in Pakistan. After Textile, sugar industry in Pakistan is the largest agro based industry with annual crushing capacity of over 6.1 million tons (PSMA, 2016).

Ayub Agricultural Research Institute (AARI), Faisalabad is the premier research organization of the Punjab province and was established in 1962 after the bifurcation of research and education working under the former Punjab Agricultural Research Institute, Lyallpur. Punjab Agricultural Research Institute, Lyallpur was established in 1906. Research System of Ayub Agricultural Research Institute, Faisalabad has released 24 sugarcane varieties so far for general cultivation in Punjab including the varieties like CoL 29, CoL 54, BL 4, Triton, CP 72-2086, CP 77-400, SPF 213, CPF 237, HSF 240, CPF 247, CPF 248 and CPF 249 (Table 5). Sugarcane varieties developed by AARI's Research System have been widely appreciated and adopted by the sugarcane growers in Punjab. During 2016-17, share of AARI's varieties in sugarcane cultivation of Punjab was 92% (Table 6).

The study in hand has been devised to assess the adoption and spread of AARI's sugarcane varieties in Punjab and to estimate the impacts of Sugarcane Breeding Research of AARI, Faisalabad from 2000-01 to 2016-17.

Table 1: Production Share of Sugarcane by Region

Region	Percentage
Europe	0
Oceania	2.2
Africa	5.7
Asia	39.9
Americas	52.3

***Source*:** (FAO, 2016)

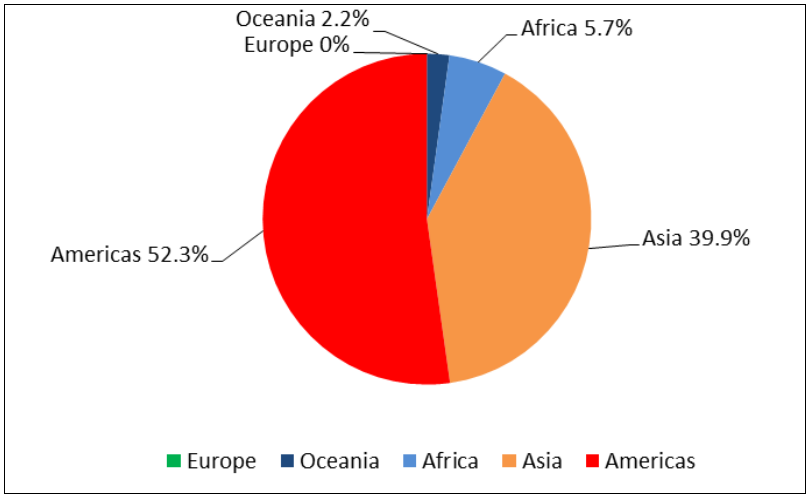

Fig 1: Production Share of Sugarcane by Region

Table 2: Global Sugarcane Production from 2001-20016

Year	Area (Million Hectares)	Production (Million Tons)	Year	Area (Million Hectares)	Production (Million Tons)
2001	19.59	1258	2009	23.72	1678
2002	20.25	1327	2010	23.68	1683
2003	20.55	1372	2011	25.54	1794
2004	20.11	1333	2012	26.06	1831
2005	19.67	1306	2013	26.91	1902
2006	20.56	1417	2014	27.05	1885
2007	22.74	1605	2015	26.66	1887
2008	24.14	1721	2016	26.77	1891

***Source*:** FAO, 2016

Table 3: Top 10 Sugarcane Producing Countries of the World

Sr. No.	Country	Sugarcane Production (Tons)
1	Brazil	768,678,382
2	India	348,448,000
3	China	122663940
4	Thailand	87468496
5	Pakistan	65450704
6	Mexico	56446821
7	Colombia	36951213
8	Australia	34403004
9	Guatemala	33533403
10	United States	29926210

***Source*:** FAO, 2016

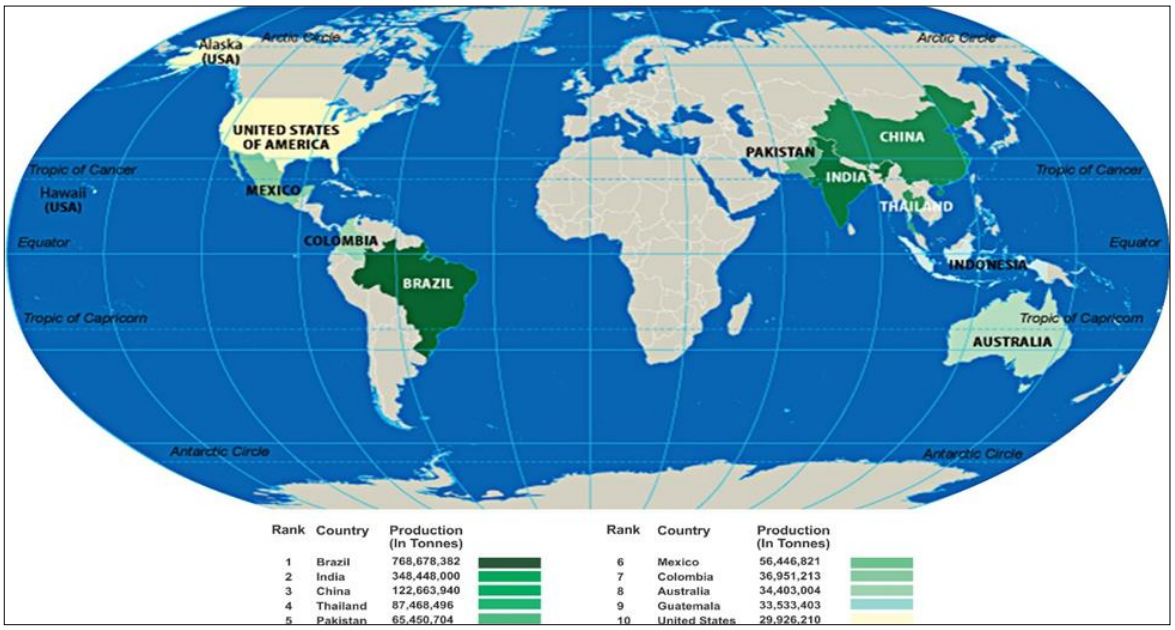

Fig 2: Top 10 Sugarcane Producing Countries of the World

Table 4: Sugarcane Area, Production and Yield in Pakistan (1947-2017)

Year	Area (000 ha)	Production (000 tons)	Avg. Yield (tons/ha)	Year	Area (000 ha)	Production (000 tons)	Avg. Yield (tons/ha)
1947-48	189.40	5529.30	29.19	1982-83	911.70	32533.50	35.70
1948-49	197.10	6946.70	35.24	1983-84	896.50	34287.30	38.20
1949-50	219.30	7849.00	35.79	1984-85	903.60	32139.60	35.60
1950-51	188.20	5506.00	29.25	1985-86	779.80	27856.30	35.70
1951-52	189.80	5399.30	28.44	1986-87	762.00	29925.80	39.60
1952-53	253.30	7265.80	28.68	1987-88	841.60	33028.80	39.20
1953-54	292.20	8956.50	30.65	1988-89	876.90	36975.70	42.20
1954-55	304.30	8920.90	29.31	189-90	854.30	35493.60	41.50
1955-56	287.30	8200.50	28.54	1990-91	883.80	35988.70	39.70
1956-57	318.10	8860.00	27.85	1991-92	896.10	38864.90	40.70
1957-58	398.60	11288.30	28.32	1992-93	884.60	38058.90	43.00
1958-59	430.20	12232.20	28.43	1993-94	962.80	44427.00	46.10
1959-60	398.20	11233.40	28.21	1994-95	1009.00	47168.40	46.70
1960-61	417.20	11640.90	27.90	1995-96	963.10	45229.70	47.00
1961-62	444.00	14356.80	32.33	1996-97	964.50	41998.40	43.50
1962-63	532.20	17993.20	33.80	1997-98	1056.20	53104.20	50.30
1963-64	491.70	16335.00	33.22	1998-99	1155.10	55191.10	47.80
1964-65	495.40	18318.40	36.97	1999-00	1009.80	46332.60	45.90
1965-66	597.30	22306.40	37.34	2000-01	960.80	43606.30	45.40
1966-67	639.80	21592.20	33.74	2001-02	999.70	48041.60	48.10
1967-68	503.90	18710.50	37.13	2002-03	1099.60	52055.80	47.30
1968-69	540.70	21971.30	40.63	2003-04	1074.50	53419.00	49.70
1969-70	620.00	26368.60	42.53	2004-05	966.40	47244.10	48.90
1970-71	636.20	23167.00	36.41	2005-06	907.30	44665.50	49.20
1971-72	552.30	19963.10	36.14	2006-07	1028.80	54741.60	53.20
1972-73	533.50	19947.50	37.39	2007-08	1241.30	63920.00	51.50
1973-74	645.60	23910.50	37.03	2008-09	1029.40	50045.40	48.60
1974-75	972.80	21241.90	31.57	2009-10	942.80	49372.90	52.40
1975-76	699.80	25546.70	36.50	2010-11	987.60	55308.50	56.00
1976-77	787.80	29523.00	37.47	2011-12	1057.50	58396.40	55.20
1977-78	822.50	30076.60	36.54	2012-13	1128.80	63749.90	56.50
1978-79	752.50	27325.50	36.31	2013-14	1172.50	67460.10	57.50
1979-80	718.50	27497.70	38.27	2014-15	1141.00	62826.00	55.00
1980-81	824.70	32359.40	39.20	2015-16	1131.00	65482.00	57.90
1981-82	946.70	36579.70	38.60	2016-17	1217.00	73607.00	60.40

***Source*:** (Agricultural Statistics of Pakistan & Economic Survey of Pakistan, Various Issues)

Table 5: Sugarcane Varieties Developed by AARI, Faisalabad, Punjab

S. No.	Variety	Year of Approval	Potential yield tons/ha	Sugar Recovery (%)
1	CoL 29	1954	69	10.10
2	CoL 44	1954	74	8.93
3	CoL 54	1963	74	9.63
4	BL 19	1966	84	9.49
5	BL 4	1968	84	10.34
6	L 116	1973	74	10.81
7	L 118	1975	82	8.23
8	Triton	1983	84	10.10
9	BF 162	1990	89	10.35
10	CP 43-33	1996	79	11.69
11	CP 72-2086	1996	84	12.35
12	CP 77-400	1996	89	11.90
13	CoJ 84	2000	89	9.80
14	SPF 213	2000	89	10.50
15	CPF 237	2000	94	12.50
16	HSF 240	2002	94	12.50
17	SPF 234	2002	99	11.60
18	SPF 245	2004	99	11.00
19	HSF 242	2006	101.1	12.50
20	CPF 243	2006	101.1	12.55
21	CPF 246	2011	104	12.15
22	CPF 247	2011	104	12.25
23	CPF 248	2013	119	12.45
24	CPF 249	2016	115	12.46

Table 6: Percent Share of AARI's Sugarcane Varieties in Punjab (2000-01 to 2016-17) (Area %age)

S. No.	Variety	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
1	SPF 213	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.12	0.34	0.60	0.27	1.05	1.18	1.14	0.69	0.72
2	SPF 234	0.00	0.00	0.00	0.00	7.18	9.64	10.28	19.47	22.34	24.08	27.94	25.30	25.31	31.23	35.02	35.26	34.54
3	SPF 238	0.00	0.00	0.00	0.00	0.00	1.94	17.51	16.29	7.35	8.61	8.49	1.86	1.42	1.28	0.00	0.00	0.00
4	SPF 245	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.06	0.07	0.36	0.43	0.53	0.96	1.65	2.42	2.62
5	CPF 246	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.75	0.00	0.00	0.00
6	HSF 240	0.00	0.00	0.00	0.00	0.00	0.00	2.35	5.72	14.15	16.81	20.23	25.52	33.95	33.96	37.07	36.01	32.14
7	HSF 242	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.43	0.47	0.48	1.06	1.11	1.02	2.39	2.13	2.91
8	CPF 237	0.00	0.00	0.00	0.00	0.00	0.00	1.71	1.22	2.55	1.14	0.72	1.12	0.95	1.55	1.77	2.71	3.63
9	CoL 54	6.32	5.60	4.02	4.00	3.13	5.18	2.73	0.54	2.91	1.28	1.26	0.80	0.63	0.53	0.11	0.06	0.00
10	CoL 29	2.09	1.50	1.26	1.10	2.00	5.11	1.42	1.71	2.00	1.01	1.38	1.01	1.69	0.91	0.23	0.00	0.00
11	BL 4	5.22	4.70	4.12	3.20	2.57	3.56	2.16	0.78	2.43	1.94	1.69	1.49	0.74	0.59	0.06	0.00	0.00
12	BF 162	9.09	11.40	10.30	12.53	12.21	10.68	8.93	9.05	5.77	3.23	4.03	2.29	1.90	1.07	0.28	0.00	0.00
13	L 118	0.13	0.60	3.88	1.20	0.67	0.00	0.00	0.54	0.79	0.00	0.78	0.00	0.74	0.37	0.00	0.00	0.00
14	CP 43-33	3.79	6.00	5.57	6.76	2.28	2.78	1.42	2.01	0.85	4.84	1.87	1.75	3.85	2.94	2.96	2.14	1.47
15	CP 722086	0.10	2.30	3.27	4.90	0.58	0.71	0.00	0.34	0.12	0.34	0.66	0.43	0.21	0.16	0.11	0.23	0.15
16	CP 77-400	0.69	3.00	3.16	5.60	8.20	5.44	3.52	4.55	5.59	5.99	6.08	7.02	7.27	6.26	5.30	4.67	5.99
17	CoJ 84	0.00	0.00	0.00	0.00	0.00	5.76	2.84	0.39	0.61	3.16	1.20	1.01	0.47	0.48	0.29	0.58	0.31
18	Triton	4.24	5.30	5.00	3.92	1.81	1.88	0.85	1.57	0.06	0.07	0.12	0.05	0.47	0.00	0.00	0.00	0.00
19	CPF 243	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	1.59	2.37	2.20
20	Others	9.87	8.10	10.76	11.62	16.78	11.13	13.10	12.62	10.68	7.90	6.93	11.75	4.79	3.32	4.22	3.17	5.01
Total		41.54	48.50	51.34	54.83	57.41	66.79	71.04	78.08	79.36	82.49	86.81	83.64	89.62	92.57	94.42	92.44	91.69

Table 7: economic impact of aari's sugarcane breeding research from 2000-01 to 2016-17 (million rs.)

VARIETY	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
SPF 213	0	0	0	0	0	0	0	11.61	15.47	49.33	120.9	72.54	328.84	361.73	348.19	208.91	243.73
SPF 234	0	0	0	0	669.65	933.86	1513.57	3328.18	4101.97	5036.87	8083.53	9951.1	11885. 16	13836.77	15428.38	15328.04	16958.68
SPF 238	0	0	0	0	0	140.3	1920.56	2076.45	1006.84	1342.73	1831.7	545.61	477.02	1590.06	74.83	0	0
SPF 245	0	0	0	0	0	0	0	7.25	9.67	13.3	90.67	145.08	205.53	369.95	631.09	913.99	1196.89
SPF 246	0	0	0	0	0	0	0	0	0	0	0	0	245.94	313.02	0	0	0
HSF 240	0	0	0	0	0	0	272.27	776.31	2063.95	2792.44	4648.54	7968.92	12079.56	11947.85	12969.42	12431.52	12531.13
HSF 242	0	0	0	0	0	0	0	20.35	96.31	120.39	169.56	508.68	605.33	547.68	1281.87	1129.27	1739.69
CPF 237	0	0	0	0	0	205.13	410.25	273.51	405.1	349.8	558.65	445.93	471.69	488.54	552.95	838.35	1266.44
CoL 54	349.71	396.82	318.8	305.97	217.69	374.23	299.38	68.61	398.34	199.59	271.57	233.89	212.06	176.72	37.42	18.71	0
CoL 29	115.63	106.29	99.78	84.11	139.07	368.99	155.89	218.25	273.53	157.97	297.49	296.19	565.36	300.35	74.83	0	0
BL 4	288.78	332.96	326.89	244.7	178.7	257.22	236.95	99.15	332.56	302.43	365.04	436.49	247.34	194.34	18.71	0	0
BF 162	290.78	466.99	472.54	554.09	490.91	446.2	566.45	667.05	456.72	291.46	502.54	387.61	367.78	204.32	54.09	0	0
L 118	7.2	42.52	308.02	91.77	46.58	0	0	68.61	108.11	0	168.92	0	247.41	123.7	0	0	0
CP 43-33	93.19	188.93	196.5	229.79	70.47	89.39	69.29	113.91	51.74	335.37	179.58	228.66	573.27	431.91	432.38	307.65	241.13
CP 72-2086	1.18	34.9	55.55	80.25	8.64	11.02	0	9.21	3.56	11.35	30.6	26.71	15.13	11.35	8.01	16.03	12.02
CP 77-400	46.39	258.41	304.37	520.68	693.11	477.64	469.3	705.09	931.03	1135.98	1595.3	2501.94	2964.42	2513.32	2115.28	1842.34	2638.41
CoJ 84	0	0	0	0	0	358.91	268.85	43.02	71.69	424.78	222.92	255.41	137.11	137.11	80.65	161.31	64.52
Triton	149.91	239.96	253.43	191.59	80.42	86.68	59.78	127.92	5.31	7.31	16.6	9.96	101.62	0	0	0	0
CPF 243	0	0	0	0	0	0	0	0	0	0	0	0	0	132.81	437.49	640.61	671.86
Others	546.89	55.86	55.86	55.86	55.86	59.85	79.8	79.8	106.4	133	166.25	199.5	226.1	226.1	239.4	239.4	239.4
Total	1889.66	2123.64	2391.74	2358.81	2651.1	3809.42	6322.34	8694.28	10438.3	12704.1	19320.36	24214.22	31956.67	33907.63	34784.99	34076.13	37803.9

2. Materials and Methods

2.1 Sources and Types of Data

Basic data used in this report include variety wise area of sugarcane in Punjab; additional yield gain of sugarcane varieties and average annual prices of sugarcane in Punjab. Data on varietal distribution of sugarcane crop in Punjab from 2000-01 to 2016-17 were obtained by the Directorate of Crop Reporting Service, Government of Punjab, Lahore. Average price of sugarcane is the support price of sugarcane announced by Government of Pakistan for the Province of Punjab in that particular year. Net yield gain attributable to an individual sugarcane variety is the difference between the yield of that variety and check variety in the breeder's trials.

2.2 Model for Estimation of Economic Impacts

The methodology used to estimate the economic implications of Ayub Agricultural Research Institute's breeding research follows a rich literature in welfare economics of agricultural research initiated by Shultz (1953) and further strengthened by Ayer and Schuh (1972) [3], Akino and Hayami (1975) [1], Huffiman and Evenson (1993) [9], Alston *et al.* (1995) [2], Heisey *et al.* (2002) [8] and Lantican *et al.* (2005) [10]. The gross annual benefits generated by sugarcane breeding research of Ayub Agricultural Research Institute in punjab were estimated by using Simple Economic Surplus Model. Lantican *et al.*. (2005) [10] used this model to assess the impacts of international wheat breeding research in the developing world from 1988 to 2002.

Following Lantican *et al.*. (2005) [10], annual benefits generated by a sugarcane variety " *i* " were estimated by using Economic Surplus Model of the following form:

$$\beta_i t = A_i t Y_i t P_i t$$

Where

$\beta_i t$ is the value of additional sugarcane produced attributable To the sugarcane variety'*i* ' in year *t*

$A_i t$ is *the* area planted to the sugarcane variety '*i*' in year *t*

$P_i t$ is the price of sugarcane in year *t*

$Y_i t$ is net yield gain attributable to the sugarcane variety '*i* '.Net yield gain attributable to an individual sugarcane variety is the difference between the yields of variety "*i*" over check variety in the breeder's trials. Using relative yield performance data from sugarcane variety trials is implicitly assumed that actual producer yields are equivalent to sugarcane variety trials yields in the breeder's experiments. *Barkley et al.* (2008) [4] argued that although the absolute level of producer yield may be over stated by experimental yield data, the relative yields between varieties are likely to be similar in both experimental and producer fields. Brennan (1984) [5] concluded that the only reliable sources of relative yields are variety trials.

3. Results and Discussion

Results of the Economic Surplus Model are presented in Table 6. It is apparent that economic benefits of AARI's sugarcane breeding research in Punjab were estimated at Rs. 1.9 billion during 2000-01. The value of additional sugarcane produced attributable to CoL 54, BF 162 and BL 4 was Rs.349.71 million, 290.78 million and Rs. 288.77 million, respectively. In the year 2001-02, farmers of Punjab were able to harvest additional sugarcane of worth Rs.2.12 billion by planting AARI's sugarcane varieties. BF 162 contributed Rs. 466.99 million toward economic impacts. The economic benefits of CoL 54 and BL 4 were Rs. 396.82 million and Rs. 332.96 million, respectively. Share of CP 77-400 in economic benefits was estimated at Rs. 258.41 million. Value of additional sugarcane produced due to adoption of AARI's sugarcane varieties in 2002-03 was Rs. 2.39 billion, out of which Rs. 472.54 million were added by BF 162 and Rs. 326.88 million by BL 4. Contribution of CoL 54 and L 118 in economic benefits was amounted to Rs. 318.80 million and Rs. 308.02 million, respectively.

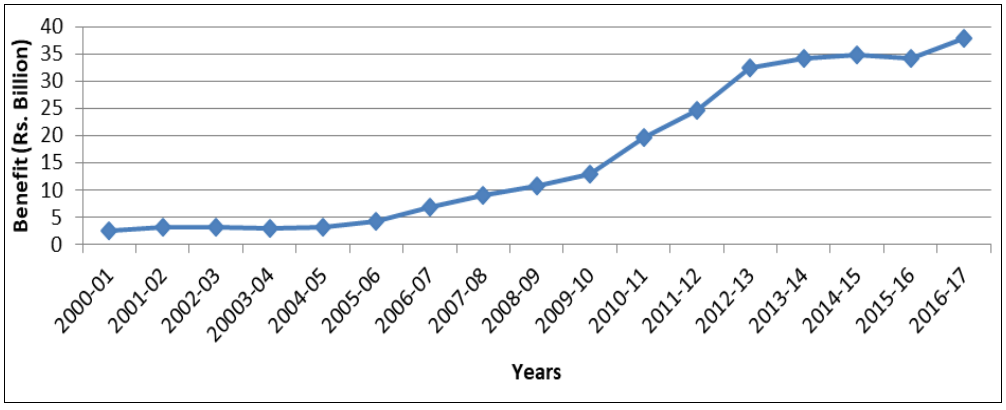

Fig 3: Economic benefits of AARI's Sugarcane Breeding Research in Punjab

In 2003-04, total economic benefits attributed to AARI's sugarcane breeding research were Rs. 2.36 billion. Share of BF 162 reduced to Rs. 554.09 million. CP 77-400 added sugarcane of worth Rs. 520.68 million. Value of additional sugarcane produced in Punjab due to CoL 54 was Rs. 305.97 million, due to CP 43-33 Rs. 229.79 million and due to Triton Rs.191.59 million. The economic benefits attributable to Ayub Agricultural Research Institute's sugarcane varietal yield improvement in Punjab during 2004-05 and 2005-06 were Rs. 2.65 billion and Rs. 3.8 billion, respectively. The highest contribution was recorded by CP 77-400 in 2004-05 with Rs. 693.11 million followed by SPF 234 with Rs. 669.65 million.

During 2005-06, SPF 234 was the largest contributing variety whose share increased from Rs. 669.65 million in 2004-05 to Rs. 933.86 million in the year 2005-06. The share of BF 162 was estimated at Rs. 490.91 million in 2004-05 and Rs. 446.20 million in 2005-06. The shares of CoL 54 and CoL 29 in additional benefits markedly increased to Rs. 374.23 million and Rs. 368.99 million, respectively in 2005-06 from Rs. 217.69 and Rs. 139.06 million, respectively in 2004-05.

During 2006-07, farmers of Punjab harvested additional sugarcane of worth Rs. 6.32 billion by planting AARI's sugarcane varieties. Variety, SPF 238 added Rs. 1920.56 million while SPF 234 added Rs 1513.57 million in economic benefits. Value of additional sugarcane produced due to CP 77-400 was Rs. 469.30 million, due to CoL 54 Rs.299.38 million, due to HSF 240 Rs. 272.27 million and due to BF 162 Rs. 566.45 million. In 2007-08, total economic benefits attributable to AARI's sugarcane varieties were estimated at Rs. 8.69 billion. Once again the main contributor was SPF 234 with Rs. 3328.18 million as additional benefits. Additional sugarcane of worth of Rs. 2076.45 million, 776.31 million and Rs. 705.09 million were added by SPF 238, HSF 240 and CP 77-400, respectively. Share of BF 162 was Rs. 667.05 million in the total economic benefits. Economic benefits attributable to CoL 29 were Rs.218.25 million and CPF 237 with Rs. 273.51 million.

Value of additional sugarcane produced due to AARI's sugarcane varieties in 2008-09 was Rs. 10.44 billion. Variety, SPF 234 remained the highest contributor among all the AARI's sugarcane varieties. Its economic impact was estimated at Rs. 4101.97 million. Economic impact of HSF 240 was Rs. 2063.95 million and SPF 238 Rs.1006.84 million. Contribution of CP 77-400 was Rs. 931.03 million while BF 162 added sugarcane of worth Rs. 456.72 million. Share of CPF 237 in additional benefits was Rs. 405.1 million and CoL 54 was Rs. 398.34 million. Value of additional sugarcane produced due to the plantation of BL 4 was Rs.332.56 million.

During 2009-10, sugarcane growers of Punjab reaped additional sugarcane of worth Rs. 12.70 billion by adopting sugarcane varieties developed by AARI's research system. Economic benefits of SPF 234 and HSF 240 were Rs. 5036.87 million and Rs. 2792.44 million, respectively. SPF 238 and CP 77-400 added additional sugarcane of worth Rs. 1342.73 million and Rs. 1135.98 million, respectively. Variety CoJ 84 contributed Rs. 424.78 million in additional benefits. Economic impact of CP 43-33, BL 4 and BF 162 was found to be Rs. 335.37 million, Rs. 302.43 million and Rs. 291.46 million, respectively.

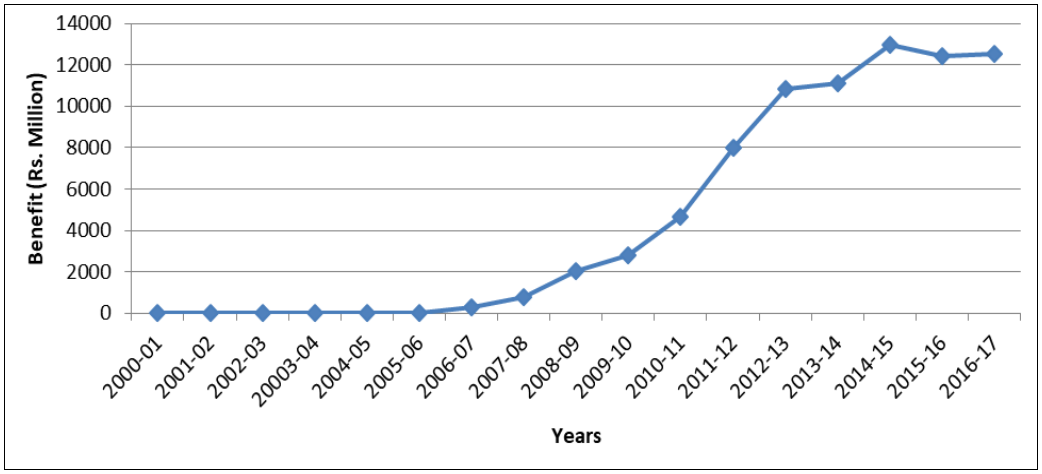

Fig 4: Economic benefits of HSF 240 in Punjab

In 2010-11, total economic benefits attributed to AARI's sugarcane breeding research were Rs. 19.32 billion. Share of SPF 234 increased considerably from Rs. 5036.87 million in 2009-10 to Rs. 8083.53 million in 2010-11 while share of HSF 240 also increased significantly from Rs. 2792.44 million in 2009-10 to Rs. 4648.54 million in 2010-11. Value of additional sugarcane produced attributed to SPF 238, CP 77-400 and BF 162 was Rs. 1831.70 million, Rs. 1595.30 million and Rs. 502.54 million, respectively. Economic impacts attributed by AARI's sugarcane breeding research during 2011-12 were Rs. 24.21 billion. Contribution of SPF 234 in economic impacts was estimated at Rs. 9951.1 million. HSF 240 contributed Rs. 7968.92 million in additional benefits. Similarly, CP 77-400, SPF 238 and HSF 242 produced additional sugarcane of worth Rs. 2501.94 million, Rs. 545.61 million and Rs.508.68 million, respectively. Share of BL 4 and BF 162 in economic benefits was Rs. 436.49 million and Rs. 387.61 million, respectively. Value of additional sugarcane produced attributable to CPF 237 was Rs. 445.93 million. Economic impacts of CoL 29, CoJ 84 and CoL 54 was estimated at Rs. 296.19 million, Rs. 255.41 million and Rs. 233.89 million, respectively.

In 2012-13, economic benefits attributed to AARI's sugarcane varieties were of worth Rs. 31.96 billion. SPF 234 was the highest contributor towards economic benefits with Rs. 11885 million. HSF 240 added Rs. 12079.5 million and CP 77-400 added Rs. 2964.42 million in economic benefits. HSF-242 added additional sugarcane of worth Rs. 605.33 million in Punjab. Farmers of Punjab reaped additional sugarcane of worth Rs. 573.27 million and Rs. 565.36 million by planting AARI's sugarcane varieties CP 43-33 and CoL29, respectively. The value of economic impact of SPF 238 and SPF 213 was Rs. 477.02 million, and Rs. 328.84 million, respectively during this year.

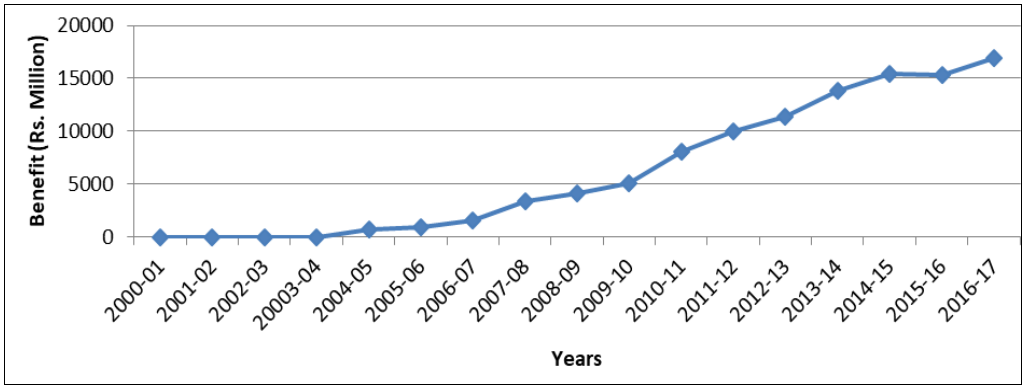

Fig 5: Economic benefits of SPF 234 in Punjab

During the crop year 2013-14, economic benefits generated due to the adoption of AARI's sugarcane varieties in Punjab were Rs. 33.91 billion. SPF 234 contributed Rs. 13836.77 million while HSF 240 contributed Rs. 11948 million in economic benefits. Contribution of CP 77-400 and CPF 238 was Rs. 2513.32 million and 1590.06 million, respectively. Varieties HSF 242 added additional sugarcane of worth Rs. 548 million in the province. Farmers of Punjab reaped additional sugarcane of worth Rs. 488.54 million and Rs. 431.91 million by planting CPF 237 and CP 43-33, respectively. Additional gain of SPF 238 and SPF 245 was of worth Rs. 1590.06 million and 369.95 million, respectively. Variety SPF 213 added Rs. 361.73 million while SPF 246 added Rs. 313.02 million in economic impactsof AARI's sugarcane breeding research.In 2014-15, additional benefits attributed to AARI's sugarcane varieties were of worth Rs. 34.78 billion. SPF 234 was the highest contributor towards economic benefits with Rs. 15428.38 million. HSF 240 added Rs. 12969.42 million and CP 77-400 added 2115.28 million in economic benefits. HSF 242 and CPF 237 added additional sugarcane of worth of Rs. 1281.87 million and Rs. 552.95 million, respectively in Punjab. Farmers of Punjab reaped additional sugarcane of worth Rs. 437.49 million, Rs. 432.38 million and Rs. 348.19 million by planting AARI's sugarcane variety CPF 243, CP 43-33, and SPF 213, respectively. The value of economic impact of CoJ 84 and CoL 29 was Rs. 80.65 million and Rs. 74.83 million, respectively during this year.

During 2015-16, additional benefits attributable to AARI's sugarcane varieties were of worth Rs. 34.08 billion. Variety SPF 234 contributed Rs. 15328.04 million in economic benefits. HSF 240 added sugarcane of worth Rs. 12431.52 million and CP 77-400 Rs. 1842.34 million in economic benefits. HSF 242 and SPF 245 added additional sugarcane of worth Rs. 1129.27 million and Rs. 913.99 million, respectively. Farmers of Punjab were able to harvest additional sugarcane of worth Rs. 838.35 million, Rs. 640.61 million and Rs. 307.65 million by planting AARI's sugarcane varieties CPF-237, CPF-243, and CP 43-33, respectively. The value of economic impact of CoL 29 was Rs. 74.83 million during this year. In 2016-17, additional benefits attributed to AARI's sugarcane varieties were of worth Rs. 37.80 billion. SPF 234 remained the highest contributor among all the AARI's sugarcane varieties. Its economic impact on Punjab's economy was estimated at Rs. 16958.68 million which was highest during the whole study period. HSF 240 added Rs. 12531.13 million and CP 77-400 added 2638.41 million in economic benefits. HSF 242 and CPF 237 added additional sugarcane of worth Rs. 1739.69 million and Rs. 1266.44 million, respectively in Punjab. Sugarcane growers of Punjab harvested additional sugarcane of worth Rs. 671.86 million, Rs. 243.73 million and Rs. 241.13 million by planting AARI's sugarcane varieties CPF-243, SPF-213 and CP 43-33, respectively.

The analysis undertaken in this study revealed that sugarcane breeding research of Ayub Agricultural Research Institute continued to generate enormous benefits throughout the whole study period. Economic impact of AARI's sugarcane breeding research in Punjab averaged Rs. 15.84 billion annually from 2001-01 to 2016-17 while it was Rs 38 billion (Fig. 3) in the last year of the study.

4. References

1. Akino M, Hayami Y. Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development. American Journal of Agricultural Economics. 1975; 57:1-10.
2. Alston JM, Norton GW, Pardey PG. Science under Scarcity: Principles and Practice for Agricultural Research and Evaluation and Priority Setting. Ithaca, New York: Cornell University Press, 1995.
3. Ayer HW, Schuh GE. Social Rates of Return and Other Aspects of Agricultural Research: The Case of Cotton Research in Sao Paulo, Brazil. American Journal of Agricultural Economics. 1972; 54:557-569.
4. Barkley A, Nalley. LL, Crespi JM. The impacts of the CIMMYT wheat Breeding program on Mexican wheat Producers and consumers: An economic welfare Analysis. (No.6931). Southern Agricultural Economic Association, 2008.
5. Brennan JP. Measuring the contribution of new varieties to increasing wheat yields, 1984.
6. Review of Marketing and Agriculture Economics. 52, 175-195.
7. Government of Pakistan. Economic Survey of Pakistan. Economic Affairs, Statistics and privatization, Islamabad, 2017.
8. Heisey P, Lantican M, Dubin H. Impacts of International Wheat Breeding Research in Developing Countries, 1966-1997. Mexico, D.F.: CIMMYT, 2002.

9. Huffman WE, Evenson RE. Science for Agriculture: A Long-Term Perspective. Ames, Iowa: Iowa State University Press, 1993.
10. Lantican M, Dubin H, Morris M. Impacts of international Wheat Breeding Research in the Developing world. 1998-2002. Mexico, D.F: CIMMYT, 2005.
11. FAO. Global Sugarcane Production. Food and Agriculture Organization of the United State (www.fao.org), 2016.
12. Schultz TW. The Economic Organization of Agriculture. New York: McGraw-Hill, 1953.