The Emergence of Sesame as a Major Cash Crop in Punjab, Pakistan: Comparative Production and Economic Analysis of the Crop for Years 2023 and 2024

Abid Hussain (Corresponding Author)
Principal Scientific Officer, Agricultural Economic Research Program, Social Sciences Research Institute, PARC-National Agricultural Research Centre (NARC), Park Road, Islamabad
Email: abid.parc@gmail.com
Nadeem Akmal
Principal Scientific Officer/ Program Leader, Agricultural Economic Research Program, Social Sciences Research Institute, PARC-National Agricultural Research Centre (NARC), Park Road, Islamabad
Khalid Mahmood
Chief Scientific Officer/ Senior Director, Social Sciences Research Institute (SSRI), PARC-National Agricultural Research Centre (NARC), and Managing Director, Oilseed Department (POD), Islamabad
Ihsan Ullah Khan
Principal Scientific Officer/ Program Leader, Oilseeds Research Program, Crop Sciences Institute, PARC- National Agricultural Research Centre (NARC), Park Road, Islamabad

Abstract
Sesame used to be a subsistence crop among the farmers of Punjab, Pakistan, with low input requirements and short maturity duration. Over the last few years, it has emerged as a major cash crop in the province. In the crop season 2024, the crop suffered significant yield losses badly affecting the farmers' income due to prolonged heat stress period and excessive monsoon rain-induced flooding This loss was mainly caused by flower-shedding caused by prolonged heat wave and excessive rains leading to flooding in the fields. Ninety-three percent of the farmers reported outbreak of various diseases in the crop. Phyllody, charcoal rot and cercospora caused damage to the crop stand to the extent of 11, 13 and 27 percent in the affected sesame fields respectively. Similarly, 95 percent of the farmers reported insect attack on the crop mainly bugs, whitefly and to some extent thrips, aphids, borers and termite. Crop sowing through seed planter in rows turned out to have productivity advantage over broadcasting. Crop variety, soil type, sowing method and sowing time should be given due consideration to avoid rain and heat stress-related damage to crop and resultant yield losses. In this perspective, crop sown early in February-March on ridges or raised beds not only matures before the onset of adverse weather conditions but also escapes

flood-related issues. While in Thal region having light sandy soil the crop can be planted in May, as extra water easily seeps down. Benefit-cost ratios of the crop production in year 2023 and 2024 were 4.00 and 1.07 without land rent, respectively. Impaired quality of the produce i.e. discoloration of the seed due to long spell of rains not only lead to decline in export volume and the total value of the commodity this year as well. Based on the last three years data, benefit-cost ratios of the crop without and with land rent were 2.02 and 1.17, respectively.

Keywords: Sesame, Heat Stress, Excessive Rains, Crop Damage, Productivity, Profitability

1. INTRODUCTION

Sesame is an important oilseed crop grown in hotter and dryer areas of Pakistan. Other important vegetable oil crops are rapeseed/mustard, sunflower, soybean and groundnut. Owing to its high quality of oil (ranging from 50 to 58 %) and high protein content (22.0%), it is described as the queen of oil crops (Shyu et al., 2002; Akintunde et al., 2004) During 2023-24, 0.287 million tons of sesame seed was produced from 0.929-million-acre area with per acre yield of 7.73 mounds. While, in year 2022-23 the area under sesame crop, total production and per acre yield in the country remained 0.607 million acre, 0.148 million tons and 6.1 mounds respectively. These figures depict an increase of 53.17, 93.88 and 26.72 percent in area, total national production and per unit area productivity, respectively in year 2023-24 as compared to previous year (Anonymous, 2024). Pakistan exported 0.097 million tons of the sesame seeds with a value of Rs.33.413 billion in 2022-23. During 2021-22, the export of this commodity remained 0.138 million tons earning Rs.32.651 billion for the country. Thus, the comparison of the export statistics of two years (2022-23 & 2021-22) showed a decrease in quantity of sesame seeds exported (Anonymous, 2023).

Over the last few years, sesame has emerged as a major cash crop being grown by many farmers on large areas and has resultantly secured a place in cropping patterns of different production systems in the province. The acreage during 2024, reached almost two million acres in the Punjab mostly planted in central and southern parts of the province. Consequently, the crop has become a big foreign exchange earnings source for the country. In Kharif season of 2024, sesame was planted on 1.762 million acres in Punjab province (making almost 95% of the total area of the crop in country), as compared to 0.930 million acres in the previous year showing an increase of 89.5 percent in acreage in 2024 over the preceding year. Keeping in mind relatively better crop productivity (7.73 mounds per acre) in 2023 and very high prices of Rs.15 to 20 thousand per 40 kg (Anonymous, 2024). Sesame farmers of the province increased the areas under this crop, expecting very good returns again this year. But contrary to expectation, significant sesame yield losses were reported during 2024 due to prolonged heat stress period and excessive monsoon rains causing flooding, leading to large scale flower shedding, physiological disorders and development of different devastating disease, insect and weeds infestations. These natural catastrophes led to huge yield losses badly affecting the farmers' income.

Given the catastrophic sesame yield reduction and resultant financial losses suffered by the sesame farmers of the Punjab province, a field survey was conducted in September, 2024 by a multi-disciplinary team of researchers from Pakistan Oilseed Department (POD), Islamabad, Social Sciences Research Institute (SSRI), NARC, Oilseeds Research Program (ORP), NARC, ,Oilseeds Research Institute (ORI), AARI, Faisalabad and Oilseeds Program, Plant Breeding and Genetics Division, NIAB, Faisalabad. The team visited fourteen major sesame producing districts of the province. There is a research gap in literature, existing studies just cover agronomic dimensions of the crop production e.g. sowing date, disease management through mutant evaluation and biological control, Sulphur fertilizer application and effect of grain legumes inter cropping & planting patterns on traits of the produce etc. In this research study, all the important aspects of sesame production i.e. area sown to per unit area productivity of the crop have been covered. Input usage in terms of kind and quantity, cost of production and profitability of the crop in year 2024 has been compared with those in year 2023.

Main objectives of the activity were to find out the causes of the crop failure in 2024, give recommendations to the concerned quarters in the country to prevent such losses in future by mitigating the impact of climate change. Specific objective of the study in socioeconomic perspective were: to determine area allocation to the crop by farm size categories at sample farms; to determine change in the area allocation at sample farms in last three years; to find out crop rotations followed in surveyed-sesame-growing-districts; to know sowing dates and methods followed by the farmers; to compare input use & production practices with recommended levels; to make comparison of productivity, prices and gross income earned by the farmers in the year 2024 over year 2023; to determine productivity of the crop by soil types and sowing methods; and to compare profitability of the crop in year 2024 and 2023

2. MATERIALS AND METHODS

In the first step, fourteen leading sesame producing districts in terms of area were selected based on first estimate of sesame crop in Punjab for the year 2024-25, and are listed in Table 1. These districts collectively constituted 85.6 percent of the total area under the crop in the province in the year 2024. Layyah remained at the top with 270,188 acres sesame acreage followed by Khaniwal and Vehari with 209,983 and 197,881 acres under sesame, respectively.

Table 1. Districts-wise sesame acreage with share in total provincial area of the crop

Sr. No.	Districts	Area (acre)	Provincial share (%)	Sr. No.	Districts	Area (acre)	Provincial share (%)
1	Layyah	270,188	15.3	9	Okara	71,967	4.1
2	Khanewal	209,983	11.9	10	DG Khan	70,392	4.0
3	Vehari	197,881	11.2	11	Bhakar	57,540	3.3
4	Faisalabad	124,058	7.0	12	Toba Tek Singh	56,836	3.2
5	Bahawalnagar	105,298	6.0	13	Jhang	37,288	2.1
6	Pakpattan	98,095	5.6	14	Kasur	24,018	1.4
7	Sahiwal	95,240	5.4	-	Total	1,507,820	85.6
8	Muzaffargarh	89,036	5.1	**-**	Punjab Province	1,761,945	100.0

Source: (Anonymous, 2024)

In the next step, a multi-disciplinary team consisting of agricultural researchers with different backgrounds; one each from Pakistan Oilseed Department (POD), Islamabad, Oilseeds Program, National Agricultural Research Center (NARC), Islamabad; Oilseeds Research Institute (ORI), AARI, Faisalabad and Plant Breeding and Genetics Division, NIAB and two from Social Sciences Research Institute, NARC, Islamabad was constituted. The team prepared checklists to assess the crop production losses and the role of different underlying causes, a detailed questionnaire to determine economics of the crop production, to find out status of the crop and issues in its production. The above team had agronomist, plant pathologist, breeders and agricultural social scientists which visited on an average five to six farms in each of the selected districts of province. Agricultural social scientists also interviewed 43 farmers from the selected districts during field visits. Sample details are presented in Table 2.

Sr. No.	Districts	Farms visited (No.)	Sample (n)	Villages of sampled farms
1	Layyah	7	4	Chak 124 TDA and Chak 146 TDA
2	Khanewal	6	3	Chak 24/10-R and Mouza Nanik Pur
3	Vehari	5	4	Chak 83 WB, Chak 97 WB, Mouza Faiz Wali and Mouza Qadir Wali
4	Bahawalnagar	7	5	Chak Kabotri, Mouza Ghalia, Mouza Bosin Dhandian and Mouza Kot Amin Khan
5	Pakpattan	3	3	Chak 36 SP Khurd and 36 SP Khurd
6	Sahiwal	7	3	Chak 61/4-R and Chak 64/5-L
7	Muzaffargarh	6	4	Gido Chowk, Mouza Qadir Pur and Kot Addu

8	Okara	4	4	Chak 47/3-R, Chak 48/3-R, Chak 23/A4-L and Mouza Dheroky
9	DG Khan	7	2	Mouza Susin Shah
10	Bhakar	8	2	Mouza Shebhan and Mouza Razat Shah Janobi
11	Toba Tek Singh	4	4	Chak 366 JB
12	Jhang	9	5	Basti, Athara Hazari, Mouza Dhabi, Mouza Kot Shakir and Mouza Dosa
13	Faisalabad	2	0	-
14	Kasur	5	0	-
-	**Total**	**80**	**43**	**-**

Table 2. Sample details by districts

This field survey was conducted in the first half of September, 2024 using pre-finalized questionnaires and checklists based on pre-testing done telephonically. The sample for the study was purposely selected in consultation with district agricultural departments to target farmers in production pockets with both healthy and affected crop. The sample included 21 (49%), 13 (30%) and 9 (21%) of farmers with small (≤ 12.5 acre), medium (12.5-24.99 acre) and large (≥ 25.0 acre) operational land holding backgrounds respectively. Along with data collection from farmers through questionnaires and checklists, general views of the farmers about sesame crop production were also noted down for viable crop rotations to avoid climatic stress damage to the crop in future. In this reference, offices of agricultural extension department in all the districts were also visited to hold thorough discussions with officials and field workers of agricultural extension department to come up with suitable solutions to the issues faced by the farmers.

3. RESULTS

Crop Situation and Damage due to Heat Spell, and Floody & Humid Field Conditions

In the areas of Bhakkar and Layya districts, to a considerable extent, and in other parts of Thal (partially Jhang and Muzafargarh districts) to some extent the seed used was mixture in nature and was mostly obtained from the grain market with no known origin. While in other areas of Punjab, about 80 % of the seed used was either of TH-6 or TS-3. The rest of the seed was either NIAB-Pearl or NIAB-Millennium. Most of the farmers (92%) reported good seed germination i.e. 70% or above, while poor (>50%) and moderate (50% to less than 70%) germination of the seed was reported by six and two percent of the farmers, respectively. Mean seed germination at the visited farms was 68%. The flowering and the extreme heat of June and July got synchronized, which led to failure of pollination and flower shedding on large scale. So, during this extreme period of heat, no pods formation and seed development occurred. This unusually high temperature in the months of June and July caused losses in the productivity due to flower shedding, pollination failure and death of plants due to physiological disorders. The heat wave coupled with June-July long spell of monsoon rains causing flooding made the situation worse because the application of plant protection measures both mechanical and chemical for control of weeds, insects and diseases was not possible. However, the losses in the March sown early crop or late sown crop of July were comparatively lower because they avoided the extreme heat of June-July.

Secondly, due to flooding caused by excessive rains, the water stayed in the fields specifically with heavy soil types for many days which caused not only leaching down of sulfur, phosphorus and nitrogen leading to the yellowing of the crop but also caused suffocation and death of the root system. More than one-third of the surveyed farmers reported flooded field conditions from two to twenty days, with a mean time duration of six days of the adverse field conditions. Flooding related damage to the crop was not reported in the areas of Thal region with light sandy soils due to seeping down of extra water.

Highest level of weed infestation was observed everywhere specifically in the fields where sowing was done using broadcast method on the flat. Weeds are first choice of different insects which not only provides shelter to them but also serves as alternate hosts. These insects not only damage the crops providing entry points for different diseases but they also serve as its carriers, especially phyllody in case of sesame. So, in addition to conducive temperature and humidity, the weeds and insect infestation played a significant role in the development of different diseases. The weeds problem in fields with line sowing was of low magnitude and so were the losses caused by them. In such fields, the weeds infestation and disease severity were of minimum level and such crops avoided the damages caused by excessive rains.

The extreme temperature coupled with flooding leading to increased humidity in the air provided a very conducive environment for development of different diseases like charcoal rot and cercosporta leaf spots etc. Ninety-three percent of the farmers reported outbreak of various diseases in the crop. Phyllody, charcoal rot and cercospora infestations were reported by 81, 64 and 33 of the farmers visited (Table 3). Phyllody, charcoal rot and cercospora caused damage to the crop stand to mean extent of 11, 13 and 27 percent at the affected farms, respectively. Phyllody, Charcoal Rot and Cercospora affected 8.96, 8.34 and 9.00 percent of the crop area at sample farms, respectively. Similarly, ninety-five percent of the farmers reported insect attack on the crop, mainly bugs, whitefly and to some extent thrips, aphids, borers and termite. Highest level of phyllody attack was observed in the fields heavily infested with insects. Farmers reported spraying plant protection chemicals two to three times in the crop season to control the diseases and insect-pest attack on the crop. Due to all these adversities, forty percent of the farmers reported plant deaths.

Table 3. Crop situation and disease incidence (n=81)

Crop Situation/ Disease Incidence	Reporting Farmers	Extent of Damage (% of the crop stand)		Affected Area at Sample Farms (%)
		Range	Average	
Germination	100 (100)	25 - 70	68	-
Disease incidence				
Phollody	66 (81)	1 - 90	11	8.96
Charcoal Rot	52 (64)	1 - 40	13	8.34
Cercospora	27 (33)	1 - 100	27	9.00
Flower Shedding	59 (73)	5 - 75	44	32.04
Plants' Death	32 (40)	1 - 80	26	10.27

Note: Figures in parenthesis are percentages

Area Under Sesame Crop at Sample Farms

Mean operational holding of the sampled small, medium and larger farmers were 4.45, 18.69 and 49.79 acre, respectively. Small, medium and large farmers allocated 50.6 percent (2.25 acre), 39.7 percent (7.42 acre) and 38.7 percent (19.27 acre) of their land holding to sesame crop in Kharif season 2024. Area allocation to the crop in farms included in the sample in last three years has increased from 1.88 acre in year 2022 to 4.26 acre in year 2023 and further to 7.38 acre in year 2024 per farm. In percentage terms, area allocation to the crop increased by 127 percent in year 2023 over that of year 2022. Similarly, it increased by 73 percent in year 2024 over that of year 2023. It means that there has been an increasing trend in area allocation to sesame crop over time.

Crop rotations dominantly followed in surveyed sesame growing districts in Punjab: Crop rotations predominantly practiced in sesame growing area/districts of Punjab are given in Fig.1. Mostly farmers sow sesame after wheat harvesting in the first half of May (66%). It is then either followed by wheat/ mustard/ canola, or kharif fodder/ seasonal maize and then by wheat. Farmers also sow sesame crop after spring maize that is followed by wheat or mustard. Another rotation is sesame sowing after mustard/canola followed by either by kharif fodder or seasonal maize. Few farmers also sow sesame crop after hybrid rice crop that is then followed by wheat crop (Fig 1).

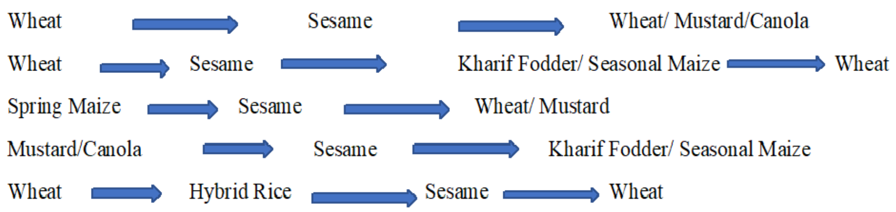

Figure 1. Main crop rotations followed by the sesame growers in a calendar year. Arrows shows sequence of crops from winter to summer to winter seasons

Inputs Level Used by the Farmers Versus the Recommended Levels

Usage of main inputs for the sesame crop in Khairf season 2024 are presented in Table 4. Farmers generally plough soil once with rotavator, two or three ploughings with cultivators followed by planking during pre-sowing land preparation. None of the farmers included in the sample reported laser levelling of the fields prior to sesame crop sowing. Recommended land preparation is ploughing the soil with cultivator two or three time, followed by one planking (Anonymous, 2024a). While sample farmers reported deep ploughing of the soil with rotavator/disc plough once, followed by two to three ploughings with cultivator and one planking. Recommended seed rate per acre for the crop varies from variety to variety i.e. one Kg for NIAB Pearl, NIAB Til-2016, NIAB Millennium; 1-1.5 kg for TS-3, TS-5 & Black King, and 1.5-2.0 kg for TH-6 & Anmol Til (Anonymous, 2024a). Thus, the recommended mean seed rate/acre is 1.2 kg, while the mean seed rate used at the sample farms was 2.24 kg per acre. Thus, the farmers used higher seed rate to extent of 1.04 kg per acre or in other words 86.67 percent more than the required level.

Sixteen percent of sample farmers reported hoeing the crop once in the production season. In this way, average number of hoeing per farm was just 0.16 with a gap of 84 percent between prescribed and actual levels. Number of irrigations for the sesame crop production usually depends on weather conditions. Generally, the crop requires 2-3 irrigations; however, in case of dry weather at pod formation one extra irrigation is also recommended. Thus, number of irrigations required for better productivity are four depending on weather conditions and soil type (Anonymous, 2024a). Mean number of irrigations in the dry crop season of year 2024 at sample farms was 3.31showing 17.25 % fewer irrigations than the recommended level for this input during dry season crop. Only few (2-3%) farmers used balanced and recommended combinations of fertilizers. Rest of them did not use standard combination of fertilizers. Rather, mean doses of DAP, Urea and Nitrophos applied at sampled farms were more or less than half bags per acre each. Thus, fertilizer application at sample farms was nearly half of the recommended level (Table 4).

Table 4. Gap between recommended and farm practices in year 2024

Production Practices/ Input Use	A. Recommended Level (No.)	B. Farmers' Practice Operations/Inputs (No.)	Gap	
			Number [A-B]	**Percent [A-B/A*100]**
1. Land preparation				
1.1 Laser land levelling	1.00	0.00	1.00	100

1.2 Deep ploughing with rotavator	0.00	0.94	-	-
1.3 Ploughing	2.50	2.48	0.02	0.80
1.4 Planking	1.00	0.90	0.10	10.00
2. Seed use and hoeing operations				
2.1 Seed use (Kg/acre)	1.20	2.24	-1.04	-86.67
2.3 Hoeing (No.)	1.00	0.16	0.84	84.00
3. Irrigation	4.00	3.31	0.69	17.25
4. Fertilizers (bags)				
4.1 DAP	1.00	0.54	0.45	46.0
4.2 Urea	1.00	0.49	0.51	51.0
4.3 NP	1.00	0.48	0.52	52.0

Comparison of Input Use, Cost of Production and Productivity in Year 2024 Over Year 2023

Levels of inputs used for the sesame crop in Kharif season 2024 and 2023 are presented in Table 5. A year on year comparison revealed a little variation in input use, prices of inputs/operation and cost of production. An increase of 4.82 % was noted in land preparation cost in the year 2024 over 2023. This study also revealed a higher level of farmers' awareness about advantages of ridge planting and crop thinning operations which is evident from increase in per acre expenditures on these operations in year 2024. Irrigation cost increased by 20.20 percent. Cost of fertilizer application remain almost unchanged with just a negligible increase of one percent in 2024 over year 2023. Due to heat stress and excessive rains, disease incidence in the crop increased, consequently, the farmers increased expenditures on disease control measures by almost five times. Land rent went up by 25.00 percent in the year 2024 as compared to the previous year. While value of the crop straw decreased by 45.79 percent, as adverse climate conditions affected both grain and straw in terms of their quantity as well as quality. On the whole, net cultivation cost with and without land rent at wholesale market gate level increased by 21.14 and 17.92 percent, respectively.

Production Practices/ Input Use	**2024**			**2023**			**Difference in cost per acre (Rs.)**
	Operations/ Inputs	**Price/ Unit (Rs.)**	**Cost/**	**Operations/ Inputs (No.)**	**Price/ Unit (Rs.)**	**Cost/ Acre (Rs.)**	
1. Land preparation							
1.1 Deep ploughing with rotavator	0.94	4158	3909	0.96	3950	3792	117 (3.09)
1.2 Ploughing	2.48	1959	4858	2.48	1823	4521	337 (7.45)
1.3 Planking	0.90	939	845	0.94	912	857	-12 (-1.40)
Sub Total	-	-	**9612**	-	-	**9170**	**442 (4.82)**
2. Seed & sowing operations							
2.1 Seed use (Kg/acre)	2.24	1210	2710	2.21	1120	2475	235 (9.49)
2.2 Broadcast/ dibbling labour (manhours)	0.38	1000	380	0.49	900	441	-61 (13.83)
2.3 Ridge/bed making/ planter	-	833	833	-	485	485	348 (71.75)

2.4 Thinning (man hours)	0.29	1000	290	0.10	900	90	200 (222.22)
Sub Total	-	-	4213	-	-	3491	722 (20.68)
3. Weeds Control (Rs./acre)	-	1484	1484	-	1321	1321	163 (12.34)
4. Irrigation							
4.1 Canal	1.41	400	400	1.44	400	400	0 (0.00)
4.2 Tubewell	1.90	855	4711	1.88	702	3791	920 (24.27)
4.3 Labour for irrigation and water course Cleaning (man days)	1.13	1000	1130	1.11	900	1001	129 (12.89)
Sub Total	-	-	6241	-	-	5192	1049 (20.20)
5. Farm yard manure (no. of trolleys)	0.07	3200	224	0.06	3200	192	32 (16.67)
6. Fertilizers (bags)							
6.1 DAP	0.54	11796	6370	0.58	12184	7067	-697 (-9.86)
6.2 Urea	0.49	4665	2286	0.58	4700	2726	-440 (-16.14)
6.3 NP	0.48	7463	3582	0.38	7300	2774	808 (29.13)
6.4 Potash/NPK	0.11	12588	1385	0.09	13217	1176	209 (17.77)
6.5 AN	0.12	4640	557	0.12	3200	374	183 (48.93)
6.6 Sulpher (kg)	0.49	640	314	0.39	580	226	88 (38.94)
6.7 Transportation and application	-	-	522	-	-	524	-2 (-0.38)
Sub Total	-	-	15015	-	-	14867	148 (1.00)
7. Insect pest control sprays	2.51	1920	4819	2.21	1812	4005	814 (20.32)
8. disease control sprays	0.29	1725	500	0.06	1550	93	407 (437.63)
9. Mark up on investment on items 1 to 7 excluding item 4.1 @ 16.87% per annum for 4 months	-	-	2239	-	-	2033	206 (10.13)
10. Harvesting charges	-	-	9116	-	-	7984	1132 (14.18)
11. Threshing charges	-	-	6292	-	-	5922	370 (6.25)
12. Land rent for 4 months	-	-	50844	-	-	40675	10169 (25.00)
13. Management charges for 4 months	-	-	2000	-	-	1600	400 (25.00)
14. Gross cost per acre with land rent	-	-	110616	-	-	95132	15484 (16.28)
15. Value of straw (Rs. per 40 kg) @ 150% of grain yield	-	-	3847	-	-	7097	-3250 (-45.79)
16. Net cultivation cost at farm level with land rent (14 – 15)	-	-	106769	-	-	88035	18734 (21.28)
17. Net cultivation cost per acre without land rent (16-12)	-	-	55925	-	-	47360	8565 (18.08)
18. Cost of transportation of the produce to market (Rs./acre)			1500			1340	
19. Net cultivation cost per acre at wholesale market gate with land rent (16+18)	-	-	108269	-	-	89375	18894 (21.14)
20. Net cultivation cost per acre without land rent (17+18)	-	-	57425	-	-	48700	8725 (17.92)

Table 5. Input use, cost of production and productivity in years 2024 and 2023

Productivity by Soil Type, Sowing Time, and Sowing Methods

Forty-four percent of the sample farmers reported loamy soil at their farms while 37 % claimed that their soil type was sandy loam type, fourteen and five percent farmers reported silt loam and clay soil types at their farms, respectively (Table 6-i). In district Toba Tek Singh, Layyah, Khanewal, Pakpattan and Sahiwal, main soil type was loam, reported by 67-75 percent of the farmers. In Jhang district, farmers reported sandy loam (60%) and silt loam (40%) soils. In Bhakar, Muzaffargarh, Bahawalnagar and Okara, both sandy loam and loamy soil types were equally reported by farmers (50% each). In DG Khan, sandy loam soil was reported by all the sample respondents. Similarly, in Vehari half of the sample farmers reported sandy loam soil, while one-fourth of the farmers reported loam and silt loam soil each. In the Kharif season of 2024, productivity of the crop was best at sandy loam soil (6.7 maunds per acre), as it has best properties of all soil materials i.e. sand, silt and clay (Table 6-i). At loam, silt loam soil and clay soils, productivity of the crop was 6.4, 5.3 and 3.7 maunds per acre, respectively.

Table 6. Productivity of the crop by soil types, sowing time and sowing methods

Soil Types/Sowing Months and Methods	Farmers (No.)	Productivity (Maunds/acre)	
		Mean	S.D.
i. Productivity by soil types			
Sandy loam (Haliki mera)	16 (37.2)	6.7	3.1
Loam (Mera)	19 (44.2)	6.4	2.7
Silt loam (Bhari mera)	6 (14.0)	5.3	2.2
Clay (Chikni)	2 (4.6)	3.7	1.3
ii. Productivity by sowing time			
February	1 (2.3)	10.0	-
March	1 (2.3)	5.0	-
April	1 (2.3)	2.0	-
May	37 (86.1)	6.45	2.99
June	3 (7.0)	4.16	4.01
iii. Productivity by sowing methods			
Broadcast	33 (77)	6.3	2.9
Broadcast followed by bed/ridge Making	4 (9)	5.7	2.6
Dibbling on beds	2 (5)	5.4	1.4
Planter	4 (9)	6.7	3.5

Note: Figures in parenthesis are percentages

Sesame crop in Punjab is mainly sown in May after harvesting wheat crop, as reported by eighty-six percent of the sampled farmers (Table 6-ii). Seven percent of the farmers reported to sow the crop in June. While, remaining farmers sowed the crop in February, March and April each. Mean productivity of the crop sown in May was 6.45 maunds per acre. Likewise, mean productivity of the crop sown in June was 4.16 maunds per acre. The crop sown in February gave the best productivity of 10 maunds per acre as the crop matured before the onset of adverse weather conditions i.e. persistent heat wave.

Seventy-seven percent of the sampled sesame growers reported sowing of the crop through broadcast method. Nine percent farmers broadcasted the seed followed by bed/ ridge making. Five percent of the sampled growers sowed the crop by dibbling seed on beds. While, nine percent of the growers sown the crop by planters in the crop season 2024. In this way, twenty-three percent of the growers followed line sowing method. Line sowing also facilitates aeration and light penetration in the crop. All the sampled farmers in Jhang, Layyah, DG Khan, and Muzzafargarh districts reported to sow the crop through broadcast method. Broad cast of seed followed by ridge/ bed making was reported by the farmers in Toba Tek Singh, Vehari, Bahawalnagar, Pakpattan, Sahiwal and Okara districts. Dibbling of seed on beds was reported in Bhakhar and Vehari districts. While use of planter was reported in Vehari, Khanewal and Bhawalnagar districts. Productivity of sesame was the highest with planter sowing i.e. 6.7 maunds per acre (Table 6-iii). While, the farmers obtained yield of the crop of 6.3, 5.7 and 5.4 maund per acre through broadcast sowing on flat land, broad cast sowing followed by bed making and dibbling of seed on bed, respectively.

Profitability and Benefit-Cost Ratio of the Crop Production

The profitability of the sesame crop production varies considerably from year to year. The main reasons are variations in the productivity as well as prices of the produce (Table 7). Last year, productivity of the sesame at the sample farms was at its best due to favorable environmental conditions i.e. 11.40 maund per acre. However, adverse weather affected the crop productivity in year 2024. Productivity of the crop was 6.24 maund per acre i.e. less than year 2023 by 45.26% due to flower and fruit shedding caused by prolonged heat wave in June/July and crop damage due to excessive rains.

Table 7. Profitability of the crop production in last three year

Benefit/ cost items	2024	2023	2022*	2022-2024
Yield (40 kg maunds)	6.24	11.40	6.10	7.91
Price per 40 kg	9841	17100	11410	12784
Gross Income	61408	194940	69601	101121
Cultivation cost at wholesale market gate with land rent	108269	89375	60693	86112

Cultivation cost at wholesale market gate without land rent	57425	48700	44026	50050
Net income per acre with land rent	-46861	106905	8908	15009
Net income per acre without land rent	3983	147580	25575	51071
BCR (with land rent)	0.57	2.18	1.14	1.17
BCR (without land rent)	1.07	4.00	1.58	2.02

* (Anonymous, 2023)

Adverse crop production conditions resulted in the production losses at sampled farms from about 8-71percent as compared to last year. Similarly, prices of the produce were 42.45 percent less than that of year 2023. Main reason of decrease in prices were glut in the market due to increase in area under the crop in year 2024 due to very high profitability of the crop in year 2023. In the same way, seed blackening/ discoloration due to rains resulted into decrease in prices of the produce and denials of the purchase of the crop produce for exports. Due to all these reasons, a substantial decrease in gross income (68.50%) has occurred this year in comparison to last year.

Similarly, the productivity in year 2022 was 6.10 maund per acre. While, average yield of the crop in last three years is 7.91 maunds per acre. Mean prices of the crop in last three years are Rs.12784 per maund. Gross income of the farmers was Rs.1,01,121 per acre. In the time period, mean cultivation cost with and without land rent were Rs.86,112 and 50,050 per acre, respectively. Net income without and with land rent are Rs.51071 and Rs.15009 per acre, respectively. Similarly, in last three years, benefit-cost ratios without and with land rent, 2.02 and 1.17, respectively. Thus, it can be said that sesame has gotten status of cash crop from subsistence farmers' crop.

4. DISCUSSION

Sesame seed and oil are used for edible purpose and the crop also has industrial applications. Three main types of oils processed from sesame are roasted oil, small mill oil and refined oil. Roasted oil is believed to be beneficial to health, and it is most commonly consumed in Japan, Korea, and China. Dehulled sesame seeds are used to enhance aesthetic value, texture and taste of various bakery products (Ayesha et al. 2020). The oil has additional use in the manufacturing of perfumes, moisturizers, cosmetics (skin conditioning agents, hair preparations, bath oils, hand products, and make-up), insecticides, paints and varnishes (Asghar and Majeed, 2013). The crop has special significance in preview of protein energy malnutrition (PEM), which is a key health problem in Pakistan Indigenously grown cultivators of crop can contribute good quality protein as well as other functional ingredients, that have potential to alleviate PEM as well as numerous allied health disorders. (Abbas et al., 2020).

Sesame used to be a subsistence crop among the farmers of Punjab, Pakistan, with low input requirements and short maturity duration. However, over the last few years, it has emerged as a major cash crop being grown by many farmers on large areas and has resultantly secured a place in cropping patterns of different production systems in the province. The cropped area during 2024, reached almost two million acres in the province mostly planted in central and southern parts. Consequently, the crop has become a big foreign exchange earnings source in the country. Findings of the current study revealed an increasing trend in area allocation to sesame crop at sample farms in last three years. The results are in line with Khan et al. 2024. They examined the trend and compound annual growth rates of sesame in Pakistan from 1971 to 2022. They reported that the crop remained stable, with favourable trends in area, production and productivity, with annual growth rates of 2.98%, 3.47% and 0.47%, respectively.

The crop suffered substantial production losses due to extended extreme heat period, excessive rains, and resultant hot & humid conditions in the crop season 2024. Islam et al. 2016 reported that biotic stresses such as diseases, insects, and pests affect the crop adversely, resulting in unpredicted losses in productivity and production. These losses are more significant where there is lack of resistant tolerant varieties. Thus, they stressed on the development of resistant cultivars to cope with biotic stresses and enhance sesame yield. They further emphasized to intensify hybrid development, as conventional breeding is unable to mobilize sufficient genetic variation. They stressed on adoption of a breeding program to grow sesame under a wider range of agroecological conditions, based on combining the resistance and tolerance traits for major constraints in each area.

As per findings of the current field survey, farmers mostly sow the crop in the first of half May. While, recommended sowing time of the crop varies with varieties i.e. for TH-3 and TH-6 it is from start of April to mid of June, and for NIAB-Pearl is from mid of April to end July **(**Anonymous, 2024a). Similarly, Thair et al. 2012 evaluated the impact of sowing date and row spacing on the yield and quality of sesame variety TH-6. They concluded that the variety may produce higher yield when sown on in mid of June, with 15 cm row spacing as it improves almost all the growth and yield related attributes. As per findings of the current study, the losses in the March sown early crop or late sown crop of July were comparatively lower because they avoided the extreme heat of June and July. Thus, it is concluded that crop sowing time should be adjusted as per varieties of the crop by replacing area under other major crops or giving rest to the land for one to two months after wheat harvesting.

Due to flooding caused by excessive rains in crop season 2024, the water stayed in the field specifically with heavy soil for many days which caused not only leaching down of nutrients leading to the yellowing of the crop but also caused suffocation and death of the root system. However, flooding related damage to the crop was not reported in the light sandy soils of Thal region due to seeping down of extra water. Hussaini et al. (2020)

also reported a higher significant effect of sandy soil on the yield of sesame crop in as compared to clay and loamy soils. They further stated crop is also tolerant to draught, but not at the germination and seedling stages, water logging, and excessive rain fall.

Wide spread weed infestation has been observed in the crop, particularly in fields where sowing was done using broadcast method on the flat. Thus, weeds' control is imperative to achieve a good crop stand and higher production. Early control of the weeds is required to achieve higher productivity. In this reference, Ijlal (2011) identified critical weed crop competition period and reported gradual decrease from 6.88 to 12.4 percent in the yield with six weeks to full season weed-crop competition. He stressed on weeds control within in six weeks after crop emergence. Weeds not only compete with the crop for nutrients but also serve as host for different insects. These insects not only provide entry points for different diseases but also serve as carrier for these diseases.

Phyllody, Charcoal Rot and Cercospora Leaf Spot (CLS) are main diseases of the crop. These diseases almost equally affected the crop in year 2024. Phyllody, Charcoal Rot and Cercospora affected 8.96, 8.34 and 9.00 percent of the crop area at sample farms, respectively. Review of literature, also confirmed these findings. Phytoplasma caused Phyllody and fungal disease like Charcoal Rot and CLS are declared serious diseases of the crop (Enikuomehin 2005; Akhtar et al. 2009; Akhtar et al. 2011). Disease susceptibility of the crop is a main cause of the low crop productivity. Root rot, wilting disease and damping of seedling is caused by transfer of fungi from soil to plant and thus effect the crop (Farhan et al. 2010). Revealing seed borne pathogens is a main factor in ensuring high production with better quality, as it directly impact seed health and vitality (Nayyar et al. 2013). Soil borne diseases are mainly controlled by systemic fungicides. Thus, production of disease-free healthy seed is a pre-requisite to achieve higher productivity of the crop, and avoid environmental and human health hazards.

In this scenario, use of appropriate plant genetic techniques like Random Amplified Polymorphic DNA (RAPD) has been suggested to control high level of genetic variation among sesame accessions collected from diverse ecologies of the country (Akbar et al. 2011). Systemic induce resistance and other disease management approaches to diminish the disease incidence are also viable but require highly proficient accuracy in measurements and long time. These include crop rotation, cultural practices, biological control method, soil solarization, seed treatment, organic soil amendments and minimum supply of soil moisture etc. (Tahir et al., 2024; Infantino et al. 2006). Sulpher fertilization can be instrumental in improving the sesame productivity and economic returns. Sulphur dose of 20 kg per acre is recommended to attain maximum sesame productivity along with higher net returns (Shah et al. 2013; Tahir et al. 2014). It is also reported that few varieties of the crop are more responsive to the Sulphur application than others, e.g. Tahir et al. 2014 found that TH-6 was more responsive than T-89.

Productivity, prices and profitability of the crop varies considerably from year to year. Quality of the seed and environmental conditions mainly cause variation in the productivity. When, production remains low in a year sesame farmer usually fetch better prices and higher profitability. In next year an increase in area under the crop occurs, and farmers usually sow the crop with poor quality seed due to non or limited availability of approved seed. Climatic vagaries further aggravate the situation by affecting both productivity and quality of the produce as happened in year 2024. Thus, farmers are to face uncertain production and marketing conditions. In spite of all this, data of last three years revealed substantial financial benefits at owner operated farms. While, tenant farmers also gain positive outcome for their hard work. Intercropping with selected crops may improve sesame farmers' profitability. As, Bhatti et al. 2015 reported that intercropping of sesame with other crops may adversely affect the productivity. However, additional harvest of intercrop compensates more than the loss in the sesame production. In this perspective, mungbean or mashbean intercropping were reported superior than other crops e.g. soybean and cowpea etc.

5. CONCLUSIONS

Sesame used to be considered as small subsistence farmers' crop as it is low cost crop with short production duration. Now, sesame has emerged as a major cash crop being grown by a large number of farmers and has gotten a place in crop patterns of different production systems. Though, profitability of the crop has decreased much in current year due climatic stress i.e. prolonged spell of heat wave and heavy rains, still the crop is a viable option for the farmers to opt. Farmers have the leverage to fit this crop in their cropping patterns from March to early July. Sesame crop harvest and post-harvest management is an alternate source of livelihood earning for the labour that was previously engaged in maize sowing, cotton picking and production activities of other major crops. Based on field observations and findings of the study following are few recommendations for obtaining better productivity of the crop.

1. To avoid heat stress and flooding induced yield losses to the crop in future, adjustment in sowing time or soil specific zoning is needed in the short run. Early sowing in late February or early March or late in the month of July would save the crop from heat wave and monsoon caused flooding of June and July, specifically during flowering period. Moreover, sowing the crop in areas with lighter soil type would help reduce magnitude of damage caused by excessive rains. In case of early or late sesame plantation instead of May, following crop rotation are considered viable to avoid climatic stress in coming years as described in Fig. 2.

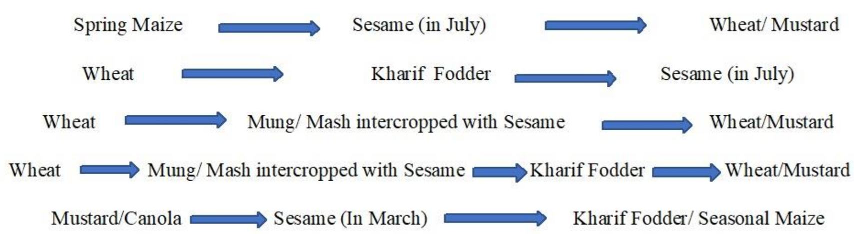

Figure 2. Viable crop rotations suggested to avoid climatic stress for a calendar year. Arrows shows sequence of crops from winter to summer to winter seasons

2. Secondly, flooding related problems that cause damage to the crop in shape of physiological disorders and diseases, can be reduced by planting the crop on ridges or raised beds in lines instead of broadcasting on flat land. The yield losses were minimum where the crop was planted in lines on ridges or raised beds.
3. Similarly, the problem of highest level of weed infestation associated with broadcast method of sowing can be solved by encouraging the farmers to sown the crop in line instead of broadcasting. Line sowing makes different weed eradication measures like manual weeding, mechanical weeding and weedicide use easier. Moreover, it also facilitates aeration and light penetration making the crop healthy and stronger and so can fight different challenges in a better way. Weed control can also minimize the chances of insect attack and so disease incidence. In the long run, heat stress tolerant varieties need to be developed.
4. The fourth important cause of the yield losses faced by the sesame farmers was insect and disease attack. If we protect the crop from insect attack, we are indirectly protecting the crop from different deadly diseases. Many of the insects not only cause injury to the crop providing entry points to different pathogen but they also serve as carrier of diseases. Phyllody in sesame is actually caused by the mycoplasma transferred by white fly, bugs and aphids. So timely spray of insecticide would not only protect the crop from the damages caused by the insect but ultimately from deadly diseases as well.
5. Seed being the most important input in the agricultural production, must be given top priority. Timely availability of seed of improved varieties with good quality should be ensured. In Thal area, over 90 % of farmers used mixed seed bought from the grain market. It played important role in the debacle of the crop in that area. Companies should be made bound to supply good quality treated seed of approved varieties labeled with all the details legally required.
6. Only a few farmers (2-3 %) used balanced combination of fertilizers while the rest did not bother about the optimal level of fertilization. The

extension department should ensure that the farmers use recommended practices for having healthy sesame crop next time.

7. For educating farmers regarding sesame crop production needs, the use of social media should be encouraged. The education should focus on how to get good quality seed, optimal use of fertilizers and specifically crop protection measures for insects, weeds and disease control.
8. The crop production technology is mainly based on farmer to farmer knowledge sharing. Though, Agriculture Extension Department started a campaign last year to raise farmers' awareness regarding sesame crop scientific production but a more robust campaign is needed to equip the sesame farmers with smart crop production practices.
9. Farmers reported high post-harvest production losses (20-25%) in sesame crop. Thus, enhanced mechanization level for crop harvesting and threshing are needed which would help bring down these losses to minimum possible level. Instead of giving farmers subsidy in cash, subsidized bed planters, harvesters and threshers should be given to them, which will minimize both pre and post-harvest losses.
10. Effective training programmes and demonstrations through cluster village approach are suggested for encouraging the farmers to adopt the recommended technology.

REFERENCES

1. Shyu, Y.S and L.S. Hwang. 2002. Antioxidative activity of the crude extract of lignan glycosides from unroasted Burma black sesame meal. Food Research International. 35: 357-365.

2. Akintunde, T.Y. and B. O. Akintunde. 2004. Some physical properties of sesame seed. Biosystems Engineering. 88 (1): 127-129.

3. Anonymous, 2024. First estimate of sesame crop Punjab 2024-25. Crop Reporting Service. 2024. Directorate of Agriculture, Crop Reporting Service, Government of the Punjab, Soil Survey of Punjab Building, Multan Road, Lahore.

4. Anonymous, 2023. Agricultural Statistics of Punjab. 2023. Bureau of Statistics, Planning and Development Board, Government of the Punjab, M.A. Johar Town, Lahore.

5. Anonymous, 2024a. Sesame Production Plan 2024. Agricultural Department, Government of Punjab, Agriculture House, 21, Davis Road, Lahore.

6. Ayesha M., M.A. Hanif, M.A. Ayub, I.A. Bhatti, M.I. Jilani. 2020. Sesame. In: M. A. Hanif, H. Nawaz, M.M. Khan and H. J. Byrne (eds.), Medicinal Plants of South Asia. Elsevier, Amsterdam, Netherlands. pp. 601-615.

7. Asghar, A. and M.N. Majeed. 2013. Chemical characterization and fatty acid profile of different sesame verities in Pakistan. American Journal of Science and Industrial Resources. 4(6): 540-545.

8. Abbas, S., M.K. Sharif, M.S. Butt and M. Shahid. 2020. Screening of Pakistani sesame cultivars for nutritive value and bioactive components. Pakistan Journal of Agricultural Sciences. 57 (3): 743-751.

9. Khan, M. N., A. M. Malik, and M. A. Rahman. 2024. Dynamics and trends of oilseed crops in Pakistan. Business Review. 19(1): 87-101.

10. Islam, F., R.A. Gill, B. Ali, B., Farooq, M. A., Xu, L., Najeeb, U., & Zhou, W. (2016). Sesame. In: S.K. Gupta (ed), Breeding Oilseed Crops for Sustainable Production. Academic Press, Cambridge, Massachusetts, United States. pp. 135-147.

11. Tahir, M., U. Saeed, A. Ali, I. Hassan, M. Naeem, M. Ibrahim, H. Rehman and H.M.R. Javeed. 2012. Optimizing sowing date and row spacing for newly evolved sesame (Sesamum indicum L.) variety TH-6. Pakistan Journal of Life and Social Sciences. 10(1): 1-4.

12. Hussaini, A., M. Usman, J.Y. Falgore, S.S. Sani, Y. Zakari and H.D. Muktar. 2020. A search for suitable growing environment for sesame production in Nigeria. Asian Journal of Agricultural Extension, Economics and Sociology. 38(8): 18-33.

13. Ijlal, Z., A. Tanveer, M.E. Safdar, A. Aziz, M. Ashraf, N. Akhtar, F.A. Atif, A. Ali and M.M. Maqbool. 2011. Effects of weed crop competition period on weeds and yield and components of sesame (Sesamum indicum L.). Pakistan Journal of Weed Sciences Research. 17 (1): 51-63.

14. Enikuomehin, O.A. 2005. Cercospora leaf spot disease management in sesame (Sesamum indicum) with plant extracts. Journal of Tropical Agriculture. 43: 19-23.

15. Akhtar, K. P., G. Sarwar, M. Dickinson, M. Ahmad, M. A. Haq, S. Hameed and M. J. Iqbal. 2009. Sesame phyllody disease: Its symptomatology, etiology, and transmission in Pakistan. Turkish Journal of Agriculture and Forestry. 33(5): 477-486.

16. Akhtar, K. P., G. Sarwar and H.M.I. Arshad. 2011. Temperature response, pathogenicity, seed infection and mutant evaluation against Macrophomina phaseolina

causing charcoal rot disease of sesame. Archives of Phytopathology and Plant Protection. 44 (4): 320-330.

17. Farhan, H.N., B. H. Abdullah and A.T. Hameed. 2010. The biological activity of bacterial vaccine of Pseudomonas putida and Pseudomonas fluorescens isolates to protect sesame crop (Sesamum indicum) from Fusarium fungi under field conditions. Agricultural Biology Journal of North America. 1: 803-811.

18. Nayyar, B. G., A. Akram, M. Arshad, S.M. Mughal, S. Akhund and S. Mushtaq. 2013. Mycoflora detected from seeds of (Sesamum indicum L.) in Sialkot, Pakistan. IOSR Journal of Pharmacy Biological Sciences. 7: 99-103.

19. Akbar, F., M.A. Rabbani, M.S. Masood and Z.K. Shinwari. 2011. Genetic diversity of sesame (Sesamum indicum L.) germplasm from Pakistan using RAPD markers. Pakistan Journal of Botany. 43(4): 2153-2160.

20. Tahir, M. N., A. Habib, G.M. Sahi, M. Sagheer, T. Murad, K. Zahid and A. Ali. 2024. Management of fusarium wilt disease in sesame (Sesamum indicum) through seed treatment and soil amendment. Phytopathogenomics and Disease Control. 3(2):261-266.

21. Infantino, A., M. Kharrat, L. Riccioni, C.J. Coyne, K.E. McPhee and N.J. Grünwald. 2006. Screening techniques and sources of resistance to root diseases in cool season food legumes. Euphytica. 147: 201-221.

22. Shah, M. A., A. Manaf, M. Hussain, S. Farooq, and M. Zafar-ul-Hye. 2013. Sulphur fertilization improves the sesame productivity and economic returns under rainfed conditions. International Journal Agricultural and Biology. 15(6): 1301-1306.

23. Tahir, M., M. A. Ibrahim, S. Tahir, A. Ayub, A. Tanveer and H. Rehman. 2014. Effect of sulfur levels on two sesame (Sesamum indicum L.) varieties under climatic conditions of Pakistan. International Journal of Plant Soil Science. 3(3): 281-288.

24. Bhatti, I.H., R. Ahmad and M.S. Nazir. 2005. Agronomic traits of sesame as affected by grain legumes intercropping and planting patterns. Pakistan Journal of Agricultural Sciences. 42(1): 10-20.