Technical Efficiency of Bell Pepper (Capsicum fruitecence L.) Growing Farms- An Opportunity to Stabilize Agriculture Economy of Oman

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Abstract— *Vegetables generally have significant importance with respect to their food value in terms of nutrition as they contain both essential vitamins and minerals. Bell pepper (Capsicum frutescence L.) is an economically important vegetable crop with the potential to increase farmers' incomes in open fields and greenhouses in Oman. Bell pepper is popular as Capsicum among customers and farmers in Arabian Peninsula countries, including Oman, with fairly moderate retail prices compared to other vegetables. Hence, a survey study investigated the technical efficiency of Capsicum-growing farms in the Sultanate of Oman. The research investigated the technical efficiency of Capsicum-growing farms of different governorates of Oman. A sample of 52 Capsicum-growing farms was selected using the multistage sampling method; the interview schedules with the farmers were conducted for data collection from January 2016 to December 2017. The data collected were subjected to the maximum likelihood method and the Cobb-Douglas stochastic frontier production model. The output of Frontier 4.1 was found to be a good fit after performing various software econometrics. Our study revealed that the mean technical efficiency for Bell pepper-growing farms in Oman was estimated to be 87%, ranging from 50% to 99%. This indicated a considerable scope of increasing capsicum yield by 13% with altering levels of inputs employed by the farmers. Further, it was observed that among the inefficiency factors, farmers' age and experience contributed significantly to the technical efficiency of the farms. Bell pepper-growing farms had enormous scope to improve their efficiency and increase productivity by following regular extension programs involving the farmers.*

Keywords— Technical efficiency, maximum likelihood method, stochastic frontier production, Frontier 4.1, Capsicum, Bell pepper.

I. INTRODUCTION

Capsicum Bell pepper (Capsicum frutescence) is an important agricultural food commodity because of its economic value and nutritional contents in terms of vitamins and minerals besides possessing natural colors from green, yellow, orange, red, etc., depending on differences in varieties and anti-oxidant compounds (Howard et al., 2012). Bell pepper is reported to be one of the world's most important fruit vegetables, along with tomatoes. Bell pepper provides essential minerals and vitamins like capsicums (Bosland & Votava, 2012). In 2020, the world's production of bell peppers was 36 million tons, led by China, which made up 46% of the total (Tridge, 2022). Globally, the capsicum market size was found to be USD 4575.3 million in 2023 and is projected to reach USD 7214.05 million by 2032. Asia-Pacific held a leading capsicum market share in 2023 (Industry Research Report, 2024).

In the Arabian Peninsula, vegetables are grown under open fields and greenhouse conditions. The investigations of ICARDA's APRP (Arabian Peninsula Research Program) have shown that growing vegetables adapting protected agriculture has proved very successful in raising the livelihoods and economic stability of the farmers in the Arabian Peninsula in general and in Oman in particular (Osman et al., 2017).

In Oman, the total cultivated area was found to increase by 3.9 percent to reach 276,000 acres by the end of 2022 compared to that in 2021 (266,000 acres) with a total agricultural production of 3.501 million tons. Vegetables with a total area of 69,074 acres produced 1.137655 million tons in 2022 (NCSI, 2022). Increasing vegetable production has been projected to contribute to government efforts to diversify the national economy (MAF, 2019). Interestingly, Capsicum production volume was also found to have surged gradually from 9.4 million kg in 2008 to 93.42 million kg in 2022, according to FAO report with code 0401 (Tridge, 2022). This increased nature of production has been considered a positive indicator of the potential opportunities for Capsicum Bell pepper cultivation in Oman and other countries (FAO, 2016; MAF, 2019).

The present study used Stochastic Production Frontier (SPF) to evaluate Bell pepper production efficiency in Oman. Earlier, many scientists used frontier applications in the field of production in non-agriculture production industries (Seiford et al., 1990; Ganley & Cubbins, 1992; Fare et al., 1994). During the same period, SPF was applied in forestry (Sanusi et al., 2017), agriculture (Fernandez-Cornejo, 1994), horticulture (Zeibet et al., 1999), olericulture (Shrestha et al., 2016; Bozoglu & Ceyhan, 2007; Julie et al., 2017) besides dairy sciences (Mbaga et al., 2003). Of late, SPF has been effectively applied to comprehend the technical efficiency of producing different vegetable crops (Wahid et al., 2017) and Okra (Ume et al., 2018; Alabi et al., 2023). Recently, Senthilkumar et al. (2018), Alabi et al. (2022), and Martinez-Reina et al. (2022) have attempted to study the technical efficiency of production in Capsicum/ Bell pepper. All these studies in agriculture have suggested effective measures for raising the production efficiency of crops. Given the above facts, the present study was undertaken to know the technical efficiency of the farms growing Bell pepper Capsicum in Oman.

II. MATERIALS AND METHODS

2.1 Data and Variables:

The primary data on Bell pepper growing farms were collected on all the aspects related to the study and recorded in the questionnaires through surveys during 2016 and 2017. The data were collected from 52 farmers growing Bell pepper Capsicum across four governorates of Oman, namely North Al Batinah, South Al Batinah, North Al Sharqiya, and Al Dakhiliya. The variables were selected based on previous efficiency studies (Belloumi & Matoussi, 2006; Mbaga, 2011; Wahid et al., 2017). The total output in kilograms was the dependent variable. In contrast, independent variables (inputs) were farm size (ha), fertilizer (kg/ha), labor (person-hours), seeds (kg/ha), irrigation water utilized (cubic meter/day), electricity charges (Omani Rials/month) and chemicals used (kg/ha). The study comprised three farm-specific variables used for the inefficiency model, viz. the farmer's age (years), the farmer's experience in farming (years), and the farmer's level of education as non-educated (zero (0)) and educated (1). The education level included illiteracy (no school), education till Class 12, and education beyond Class 12.

2.2 Analysis of Technical Efficiency:

The survey data were subjected to the analysis of the efficiency of Bell pepper production using both SHAZAM econometric software and the Coelli (1996) "FRONTIER 4.1" computer program. The software referred to as SHAZAM is a very comprehensive tool for measuring econometrics, statistics, and analytics. It is popular worldwide as it offers various computations such as building models, checking hypotheses, and explaining the variation among different variables.

2.3 Analysis of Technical Inefficiency:

The Stochastic Frontier Production (SFP) function model (approach) was used to assess the technical inefficiency of Bell pepper-growing farms in Oman, as suggested by Battese and Coelli (1995).

III. RESULTS AND DISCUSSION

The maximum likelihood estimates for Bell peppers are presented in Table 1. The model indicated that variables such as farm size, electricity, and water were positive for Bell pepper production output with a significance of about 5%. This meant that these parameters led to an increase in the output. The coefficient of electricity has the highest value, followed by water and farm size. The estimate of Bell pepper production as a result of a unit increase in electricity was found positive (34.74) and significant. This meant that 1 unit increase in input (electricity, OMR) would increase Bell pepper output by 34.7 kilograms. On the other hand, labor, seeds, chemicals, and fertilizer were found to be negative, with a significance of about 5%.

In the inefficiency model, we had the farmer's age, the farmer's experience, and education. Farmer's age and experience were found to be positive, which meant older and much more experienced farmers tended to be much less efficient, with a significance of 5%. The farmer's age coefficient was positive (0.2) by a priori expectations. This indicated that age increases inefficiency and reduces efficiency, meaning that older farmers tended to be much more technically inefficient than their relatively younger counterparts. The other two factors, like education level, had also negative signs but were insignificant ($p>0.05$), which was also observed by Haji and Andersson (2006).

TABLE 1
MAXIMUM LIKELIHOOD ESTIMATES OF THE COMMON STOCHASTIC PRODUCTION FRONTIER FOR BELL PEPPER

Variable Name	Parameter	Coef.	Standard Error	T-Ratio
Stochastic Frontier Model				
Constant	B_0	-1.08	0.88	-1.23
In(X1)(Farm size)	β_1	2.22	0.87	2.57
In(x2)(Fertilizer)	β_2	-2.65	0.78	-3.39
In(X3)(Labor)	β_3	-5.79	0.88	-6.6
In(X4)(Seeds)	β_4	-2.37	0.88	-2.69
In(X5)(Water)	B_5	3.8	0.74	5.12
In(X6)(Electricity)	B_6	34.74	7.99	4.35
In(X7)(Chemicals)	B_7	-34.59	7.81	-4.43
In (X1)*In (X1)	B_8	0.45	0.74	0.61
In (X2)*In (X2)	B_9	-0.34	0.14	-2.5
In (X3)*In (X3)	B_{10}	-0.04	0.84	-0.04
In (X4)*In (X4)	B_{11}	-0.47	0.4	-1.17
In (X5)*In (X5)	B_{12}	-0.44	0.05	-9.56
In (X6)*In (X6)	B_{13}	-19.36	0.38	-50.42
In (X7)*In (X7)	B_{14}	-9.61	0.57	-16.98
In (X1)*In (X2)	B_{15}	-0.43	0.67	-0.64
In (X1)*In (X3)	B_{16}	-0.94	0.85	-1.11
In (X1)*In (X4)	B_{17}	-0.55	0.81	-0.68
In (X1)*In (X5)	B_{18}	-0.08	0.58	-0.14
In (X1)*In (X6)	B_{19}	-17.49	0.76	-23.09
In (X1)*In (X7)	B_{20}	16.27	0.76	21.55
In (X2)*In (X3)	B_{21}	-0.04	0.45	-0.08
In (X2)*In (X4)	B_{22}	-0.2	0.19	-1.03
In (X2)*In (X5)	B_{23}	-0.01	0.41	-0.02
In (X2)*In (X6)	B_{24}	-3.02	0.5	-6.09
In (X2)*In (X7)	B_{25}	3.15	0.63	5.03
In (X3)*In (X4)	B_{26}	0.35	0.75	0.47
In (X3)*In (X5)	B_{27}	0.29	0.63	0.46
In (X3)*In (X6)	B_{28}	85.55	8.77	9.75
In (X3)*In (X7)	B_{29}	-85.46	9.76	-8.76
In (X4)*In (X5)	B_{30}	-0.11	0.33	-0.34
In (X4)*In (X6)	B_{31}	6.37	0.69	9.26
In (X4)*In (X7)	B_{32}	-6.59	0.7	-9.36
In (X5)*In (X6)	B_{33}	-54.45	8.59	-6.34
In (X5)*In (X7)	B_{34}	53.36	9.56	5.58
In (X6)*In (X7)	B_{35}	28.33	9.71	2.92
Inefficiency Model				
Variable Name	**Parameter**	**Coef.**	**Standard Error**	**T-Ratio**
Constant ($^{\delta}0$)	$^{\delta}{}_0$	-0.35	0.81	-0.43
Farmer's Age (Z1)	$^{\delta}1$	-0.2	-0.1	2.03
Farmer's Experience (Z2)	$^{\delta}2$	-0.22	-0.1	2.21
Education Dummy (Z3)	$^{\delta}3$	-0.34	0.29	-1.2
Sigma Square	$\sigma 2$	1	0.24	4.18
Gamma	γ	0.01	0	6.77

The maximum likelihood estimates of the Stochastic Frontier for Bell peppers are presented in Table 2. The results revealed that the mean technical efficiency for Bell pepper farms in Oman was 87%, ranging from 50% to 99%. This indicated the possibility of increasing Bell pepper output to 13% with the current level of inputs used by farmers for cultivation. Further, more than half of the farms (55%), the Bell pepper growing farms in Oman, were observed to be efficient to 90 to 100%. This was followed by 19% of the efficient farms, between 80% and 90%. Similar observations have been noted from the histogram showing the distribution of technical efficiency scores of Bell pepper growing farms (Fig. 1). As many as 29 farms out of 52 had technical efficiency beyond 90%, which can be treated as the best farms. In contrast, the remaining 23 farms were found efficient from <60% (5) to 80 to 90% (10). These figures clearly showed at least a 10% scope for improving the efficiency of Bell pepper production with current levels of inputs used by farmers in Oman.

TABLE 2
A SUMMARY OF THE MAXIMUM LIKELIHOOD ESTIMATES OF THE COMMON STOCHASTIC FRONTIER FOR BELL PEPPER

Efficiency Index (%)	Study Sample	
	Number of Farms	Percentage (%)
Less than 60	5	10
Between 60–70	3	6
Between 70–80	5	10
Between 80–90	10	19
Between 90–100	29	55
Mean Efficiency	87%	
Median	95%	
Maximum	99%	
Minimum	50%	
Standard deviation	2	
Sample size	52	100

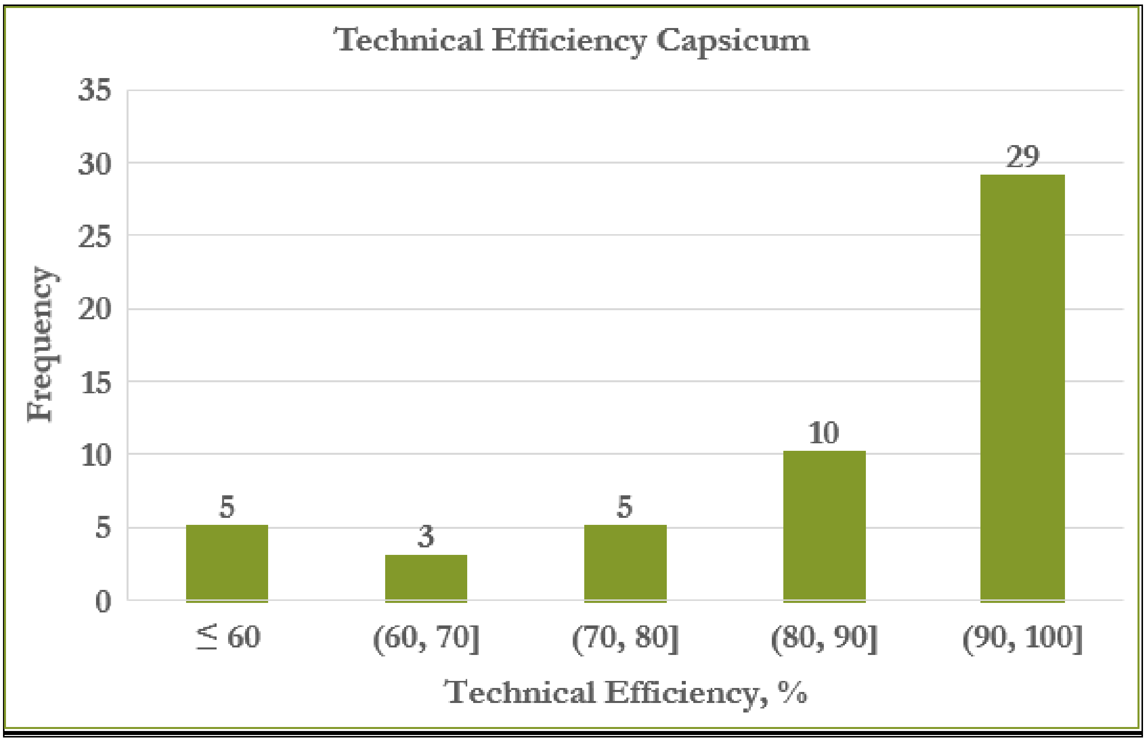

FIGURE 1: The distribution of technical efficiency scores of Bell pepper growing farms in Oman

The range of technical efficiency of Capsicum production observed in the present studies was similar to the findings of research conducted elsewhere in the world. Ogunbo et al. (2015) reported that the mean technical efficiency of pepper (Capsicum annuum Mill) production was 0.64. The authors considered that the current production frontier was only relatively efficient and that improved high-yielding pepper cultivars and training in their use could improve pepper production efficiency in Nigeria. In the study of Hina et al. (2017), the mean technical efficiency was estimated to be 83.64 percent, indicating that output could be raised by 16.36 percent through efficient crop management practices without actually increasing the levels of inputs. Senthilkumar et al. (2018), however, reported the average technical efficiency of sampled capsicum farms under protected cultivation to be 83.64 percent with optimization of the production frontier of the capsicum cropping system by overcoming the existing level of technical inefficiencies related to farmers' experience in India. Martinez-Reina et al. (2022) reported the mean technical efficiency of the sweet chilli (Capsicum chinense) to 81% in the Colombian Caribbean, which was suggested for improvement with increasing labor and weed management inputs. Similarly, Alabi et al. (2022) observed that mean technical efficiency was 79%, leaving a gap of 21% for improvement for the smallholder pepper (Capsicum species) production in Abuja, Nigeria, through addressing the challenges of inadequate rainfall through proper irrigation policies.

The present study covers a sample of 52 farms growing Bell peppers across prominent vegetable-growing wilayats of four governorates of Oman, namely North Al Batinah, South Al Batinah, North Al Sharqiya, and Al Dakhiliya. The joint document of FAO with the Ministry of Agriculture & Fisheries on the Sustainable Agriculture and Rural Development Strategy (SARDS-2040) towards 2040 of the Sultanate of Oman listed Bell pepper as one of the lead vegetable crops in terms of land and water consumption. Our results revealed the potential of increasing Bell pepper production to 10-13% with levels of inputs/ variables studied. This indicated that an increase in vegetable production could be the key to attaining not only self-sufficiency in the agricultural sector but also to maintaining economic sustenance through diversification of crops for cultivation as highlighted in SARDS-2040 developed by FAO along with Ministry of Agriculture & Fisheries, Sultanate of Oman (FAO, 2016; AlSalmi et al., 2020). The above observations would also apply to all GCC countries (Gulf Cooperative Council), the Arabian Peninsula, and the world.

IV. CONCLUSION

The mean efficiency level of Bell pepper was about 87%, indicating that 13% of the scope existed to raise the efficiency of production to 100% with the levels of inputs considered in the study. Intensifying extension activities on Bell pepper cultivation among the farmers and organizing training programs to improve their skills would increase Bell pepper productivity.

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CONFLICT OF INTERESTA

Authors declare that they do not have any conflict of interest.

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