Risk-Efficient Fumigant-Mulching System Alternatives for Bell Pepper Production

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Abstract

As methyl bromide (MB) is phased-out for complete banning for agricultural use, this research evaluates the relative economic efficiency of fumigant alternatives, in combination with mulching methods. Bell pepper production in Georgia was studied in particular because any fumigant system that works for it would also work for other commercial crops. This study employs stochastic dominance techniques to identify the most efficient and preferred production alternatives in terms of gross and net enterprise returns. Based on risk efficiency, mean returns and the decision-maker's risk aversion considerations, this analysis identified TELV-MS, TEL-MS, and PC250-MS as the most preferred and risk-efficient alternatives.

Introduction

Fumigation has played an important role in the production of many commercial vegetables in Georgia and the rest of the country. Although several chemicals have been used as fumigants in the past half century, methyl bromide (MB) has been the most extensively used because of its easy application, low cost, and superior performance. Moreover, it has also been used to control pests and obnoxious weeds like nutsedge, which are most prevalent and problematic in Georgia.

On January 1, 1995, the Montreal Protocol recommended the banning of methyl bromide for agricultural use as it was added to the list of ozone depleting substances. An accelerated phase-out schedule for the chemical was laid out at the Ninth Meeting of the Parties in Montreal in 1997. This became a major concern to many U.S. farmers, particularly those in Georgia, where the chemical has been used in the production of many commercial vegetable crops. As a temporary relief during the phase-out period, a Critical Use Exemption privilege was made available to farmers who could provide adequate proof of economic hardship resulting from abstaining from using methyl bromide in their farm operations. This exemption was granted only to growers who lack a readily available substitute and therefore were unable to carry out agricultural production without methyl bromide (Byrd et al., 2006). Under the critical exemption use, methyl bromide was allowed to be used on squash, tomatoes, pepper, cantaloupe, eggplant, and cucumber production in Georgia. However, as some farmers gained temporary access to methyl bromide, its prices increased and supplies declined (Kelley, 2009). Consequently, the task of finding more viable and effective alternatives has become all the more crucial.



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This study utilizes experimental data collected on various fumigant substitutes for bell pepper production. Bell pepper has been the most logical choice for the field trial experiments given the scientists' assertion that any fumigant system that would work for bell peppers should also work for other commercial crops. In addition to analyzing chemical fumigant alternatives, several mulching methods were also introduced as complementary weed suppression techniques. Thus, the ultimate goal of the field trial experiments was to identify the most reliable and efficient pair of fumigation and mulching alternatives that would result in the most optimal fumigation and weed suppression benefits. In this analysis, the most preferred production method is identified based on their resulting yield, income, and risk efficiency. Most studies are prone to evaluate production options by singling out those that produce the most productive and profitable alternatives. However, this study also considers risk efficiency that takes into account the variability or fluctuations in realizing yields and revenues over time.

Previous studies have used different forms of yield analysis in comparing the effectiveness of several production alternatives. According to Culpepper, David, and Webster (2006), results of the nutsedge control in the field trials indicate that most treatments were comparative to methyl bromide except for 1,3-dichloropropene plus chloropicrin (TEL) and metam sodium (TELV) under traditional low density black on black polyethylene mulch (LDPE). This control method resulted in higher pepper yields. On the other hand, the methyl iodide plus chloropicrin (MIDAS) under high barrier silver on black metalized mulch (VIF-D) system had lower yield per acre.

This study goes beyond the analysis of yield efficiency by translating the collected yield data into revenues and incomes to present a more realistic assessment of comparable financial efficiencies of the different production methods. In other words, this study will identify the most preferred combination of fumigation and mulching methods that produces the most favorable streams of revenues and cost-savings over time. This task is accomplished through the use of stochastic dominance analysis that is designed to evaluate both the levels and variability of the returns and costs associated with the production methods.

Fumigation – Mulch Systems

This study utilized yield data obtained from field experiments conducted in 2006 at the University of Georgia, Tifton Campus. The field trials considered pairings of fumigant and mulching methods from a set of five fumigant treatment and four mulching alternatives designed by university extension scientists (Culpepper, 2006). The experiments were intended to determine effective strategies to control nutsedge and minimize the presence of nematodes, a destructive pest that attacks the root system of vegetable crops, thereby significantly reducing yield. The experiments also include a base method using methyl bromide and a control treatment system for purposes of comparison. The fumigant and mulch alternatives are presented in Table 1 with their corresponding cost per acre and abbreviations, which shall be used to refer to the various systems in the rest of the paper.

This study paired each fumigant factorially with every mulching method, thus resulting in 28 fumigant-mulch (production) alternatives. The experiments spanned through five successive weeks of harvest, which approximates a normal production cycle that typically averages four harvests. Correspondingly, yield data were permutated by allowing for five replications per alternative.

Enterprise budgets for bell pepper developed by the UGA Extension and Agricultural Economics Team were used to calculate gross and net return values for each production alternative based on the yield data and cost estimates obtained from the field experiments (Ferrer et al., 2010). Experimental yields were extrapolated to acre-scale revenues given that the size of the experimental plots was about 0.1 percent of an acre. In addition, both gross and net return measures were calculated under five possible risk-rated pricing outcomes, namely best, optimistic, median, pessimistic, and worst. The "median" price obtained from interviewing Georgia bell pepper growers and Extension County Agents was the average price they received 50 percent of the time. The "optimistic" and "best" represented a 16 and 33 percent increase in price, while "pessimistic" and "worst" represented a 16 and 33 percent decrease in price, respectively. Additional input prices such as fertilizers, mulches, fungicides, and other chemicals for pest and disease control were obtained from vendors, farmers, and Extension County Agents respectively (Fonsah et al., 2007; Fonsah and Hudgins, 2007; and Fonsah et al., 2008).

Stochastic Dominance Analysis

Stochastic dominance resolves risky choices by setting criteria for establishing risk-efficient alternatives available to producers when faced with uncertain outcomes. Above and beyond examining the revenue structures of production alternatives, this approach evaluates tradeoffs between treatment levels and riskiness of the revenue variable. After all, a production alternative that brings in the highest average revenue or incurs the least average cost will not necessarily be the most beneficial alternative to a producer. This seemingly favorable alternative can possibly be dominated by another production method with a steadier stream of "acceptable" revenues and incomes (i.e., less variability or riskiness) over time. Stochastic dominance analysis, thus, recognizes that uncertainty is an inevitable component in decision making, especially at the farm level. In this analysis then, preferred "risk-efficient" production alternatives are identified by considering tradeoffs between the levels (averages) and riskiness (variability or fluctuation) of gross and net returns. Moreover, the application of the stochastic dominance framework in this study allows for a ranking of alternatives based on producers' risk preferences for the most risk-efficient set of yields and revenues.

Several variations of stochastic dominance have been developed independently, but they are all based on either first- or second-degree application. Second-degree stochastic dominance analysis adds a risk aversion assumption for the agent's decision making preferences. It eliminates dominated or inefficient distributions and is capable of ordering a larger set of distributions than that which can be ordered under the first-degree (Hadar and Russell, 1969). However, second-degree stochastic dominance is not a very discriminating instrument due to the presence of crossings distribution plots. This makes dominance rankings of distributions difficult to distinguish (Figures 1 and 2). To deal with this problem, Hammond (1974) recommended the use of the constant risk-aversion preference function which ranks alternatives according to risk aversion parameters based on decision maker preferences.

Following the lead of Hammond, we derive these parameters, hereby referred to as risk aversion coefficients (RAC), by adopting the constant absolute risk aversion (CARA) model, established by Babcock et al. (1993). RAC for low and high risk scenarios were set at 0.000004 and 0.346574 respectively, to reflect the range of risk averse behavior. These ranges should allow us to capture any variation among alternative rankings. Correspondingly, the risk neutral condition RAC was set to 0. This model was chosen since it does not exhibit susceptibility to risk (Nelson and Escalante, 2004).

This model was applied to measures in both gross revenue and net returns per acre. These two variables allowed for the analysis of the combined influence of yield and input prices on risk efficiency and production costs alone. The net returns measure evaluates the potential profitability and indirectly addresses the financial efficiencies of alternative systems. On the other hand, the gross revenue analysis captures productivity or yield efficiency analysis since the output prices used across the 28 systems were constant.

Results

Gross Returns: Best and least preferred systems

Tables 2 and 3 present summaries of the results of the stochastic dominance analysis based on gross and net returns, respectively. In the results tables, the fumigant-mulch pair TELV-MS, with the highest mean revenue at $16,362 per acre and a coefficient of variation (measure of risk) of 46.10 was the most dominant system under all levels of risk aversion. Following TELV-MS in descending order of mean revenues under the low risk aversion situation were MB-MS, MIDAS-MS, PC250-MS and TEL-MS (Table 2). Notably, the ranks of the fumigant systems paired with MS, the most economically efficient mulching system among the four options (Ferrer et. al, 2010), outperformed the risk-efficiency of all other systems, indicating that MS is a good complement to all fumigant alternatives we have considered. In fact, the five most preferred alternatives adopted this mulching method (Table 2).

The rankings based on gross revenues changed under the high risk aversion scenario. Even though the relative variability of TELV-MS was satisfactory at best and the coefficient of variation for MB-MS and MIDAS-MS were lower, each alternative managed to be consistently ranked in the top three. The latter two alternatives could not surpass TELV-MS due to their mean gross revenues of only $16,023 and $15,563 per acre, respectively. The high barrier black on black blockade mulch (S), paired with MB fumigant method (denoted MB-S) performed significantly better with a high RAC, ranking fourth while ending up with a ranking of 18th at the low RAC. The better ranking of this alternative was consistent with the fact that this method yielded the lowest relative variability of 39.99 among all the production systems. Interestingly, certain production alternatives with high mean revenues performed poorly in the high risk aversion situation (vis-à-vis their results under low risk aversion), such as TEL-MS which dropped from rank fifth to 20th and TELV-LDPE demoted from rank sixth to 23rd. These drops in rankings can be explained by their relatively high level of riskiness as indicated by their coefficients of variation of 47.96 and 49.15, respectively.

The least preferred system under risk neutral and low risk aversion analysis was MIDAS-VIF-D, which registered the lowest mean gross revenue of $11,304 per acre, despite having low relative variability of 42.71. Under high risk aversion conditions, PC400-LDPE was the weakest option with a high variability of 49.45, while NF-S, i.e., mulching method S with no fumigant (NF), was consistently ranked in the bottom three across all levels of risk aversion due to its highly volatile revenues (coefficient of variation of 50.42).

Net Returns: Best and least preferred systems

This analysis expands the gross revenue analysis by introducing estimates of actual production costs to derive the net returns data. Fixed and fumigation costs per carton were provided in Table 3 to help the reader understand the derivation of net returns and also to explain the changes in rankings relative to the gross revenue stochastic dominance analysis. Most producers regard MB as a very cost-effective option, but this analysis will reveal other more dominant cost-effective alternatives. The results in Table 3 indicate that MB was much less dominant across all risk aversion categories as its use did not result in significant cost savings that could dominate the other options. The inclusion of differences in cost structures among the various production alternatives only magnified distinctions in the ranking of preferred methods. Specifically, TELV-MS continued to be the most dominant alternative for a risk neutral and more risk averse decision maker while MIDAS-VIF-D remained the least preferred. TELV-MS was more cost efficient than all the MB alternatives and provided the highest net returns of $5,416 per acre with a low coefficient of variation of 136.22. On the other hand, production using MIDAS-VIF-D resulted in a net loss of $1,712 per acre and was the only alternative that generated loss upon application. This was due to the fact that it had the most expensive production system, as shown in the cost information found in Table 3.

Interestingly, the results indicate that a more risk-averse decision maker would tend to prefer options that do not involve fumigation in several occasions. For instance, a farmer would be better off using NF-LDPE and settle with a $4,655 net return per acre due to its low net returns volatility of 132.19 (Table 3). The second and third dominating options also call for no fumigation (NF-VIF-D and NF-MS), suggesting that producers were better off switching to the control production system under high risk situations. The control system in this study did well due to the fact that when the experiment was initially conducted, only the first crop in the area with low nematode and disease pressure was considered, given the initial focus on nutsedge control. Nematodes tend to upsurge on the second and third crops if fumigant is not applied. In the grower fields, crops will be destroyed by nematodes and disease through the buildup of weeds in the second and third crop under the non-treated system.

Based on all these results, it is evident that not all MB fumigant substitutes used in the field trials were economically dominant or more efficient than MB itself. Some alternatives ranked lower in every risk category for both gross revenues and net returns analysis. These results can be explained by the composite effects of input prices, productivity, and effectiveness in controlling nutsedge and nematode issues. Other alternatives, however, were found to produce more dominant and favorable results than MB after their production cost structures were factored in.

Moreover, the rankings between risk neutral and low risk aversion scenarios both in the gross and net returns analysis were identical except for NF-LDPE and PC250-VIF-D for gross revenues and NF-LDPE and NF-MS for net returns, which basically switched ranking position with one another. This indicates that farmers' choices are not necessarily influenced by changes in their levels of risk aversion.

Summary and Conclusions

This study presents an economic and financial perspective in assessing the relative efficiencies of possible methyl bromide alternatives, in combination with certain mulching methods. Results of this analysis identified certain fumigant alternatives that performed better than MB under an analytical framework that considered both yield and risk efficiency. Specifically, the production alternative TELV-MS dominated all fumigant-mulching systems considered, including those that involved MB. This alternative was consistently ranked first across all levels of risk aversion both for gross and net returns rankings. Under conditions of low risk aversion and risk neutrality, TEL-MS and PC250-MS were the second and third best options after both output price changes and cost structures were considered.

Conversely, MIDAS-VIF-D was the least favored alternative across all levels of risk aversion as this option registered net losses due its high cost structure. The gross and net rankings were almost comparable, thus implying that the decision-maker's risk aversion could possibly not be a significant influence in the farmer's rankings of alternatives. Moreover, MB systems have usually been dominated in the rankings based on net returns.

Our findings suggest that economically viable MB alternatives exist for Georgia pepper producers. However the successful adoption of these alternatives depends on various factors. Consequential adoption could vary based on the alternatives' consistency, efficiency, and reliability across different farm conditions and over longer periods of time. Further, more research is needed to compare alternatives to the benchmark performance of MB under more elaborate experimental conditions. MB has proven its ability to eradicate diseases and pests over a wide range of environmental and growing conditions over time. In this regard, only actual on-farm use of the suggested fumigants can establish whether the alternatives are equally adaptable to varying farm conditions.

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Figure 1. Comparison of the top and bottom three production systems' CDF series for the gross revenue data

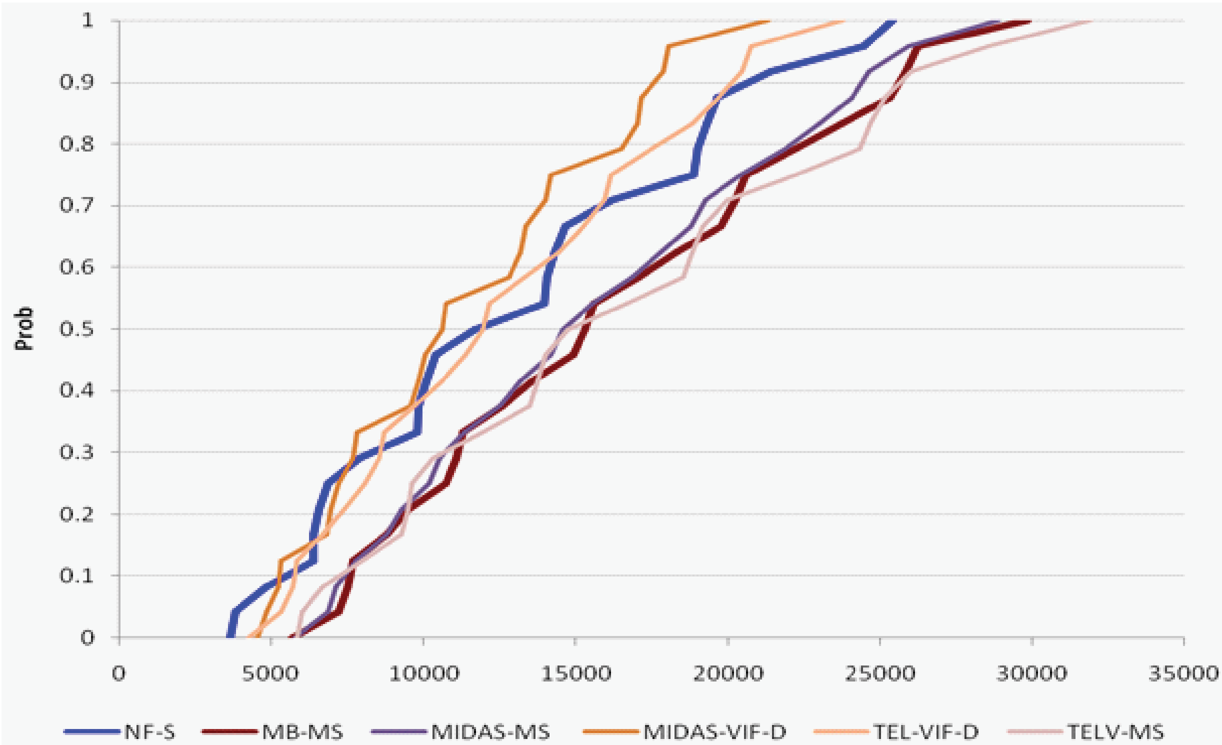

Figure 2. Comparison of the top and bottom three production systems' CDF series for the net returns data

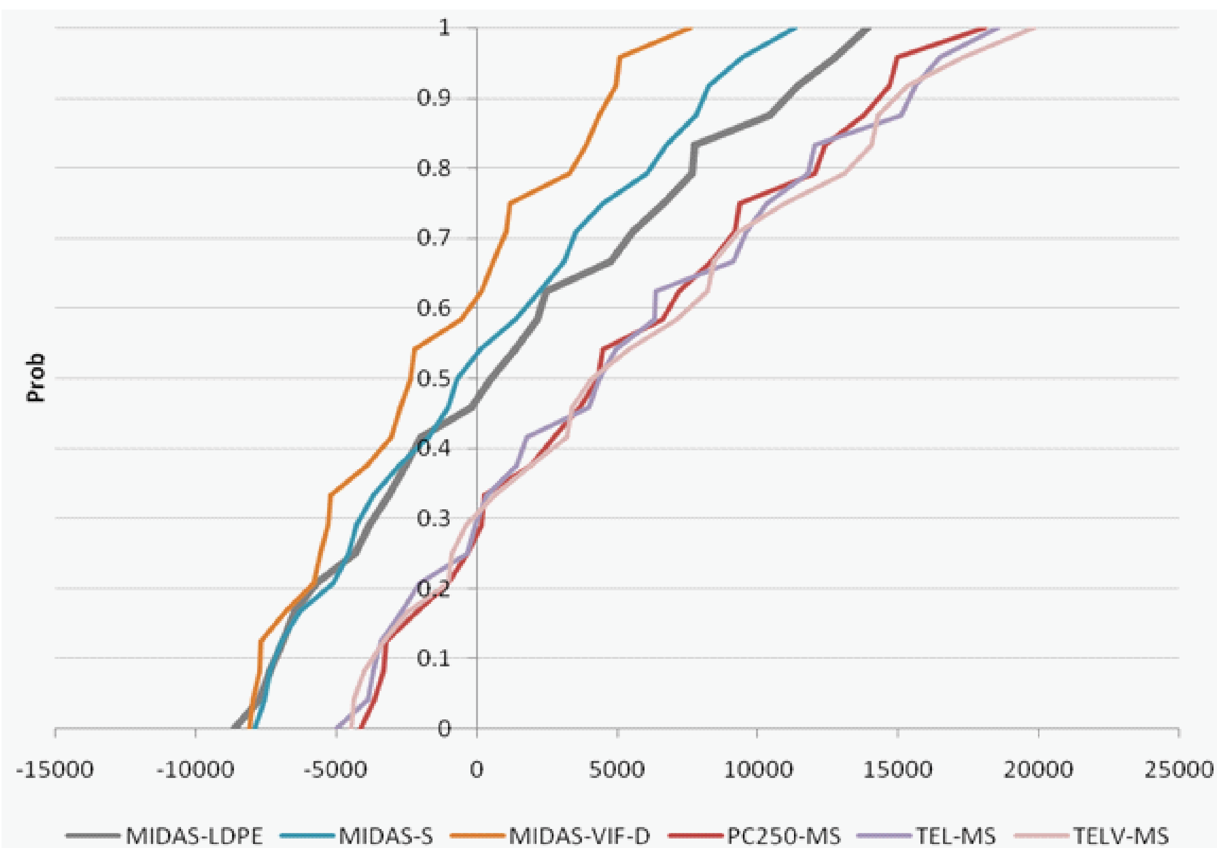

Table 1. Cost per acre of the alternative fumigant and mulch systems

	Abbreviation	Cost per Acre ($/acre)
Fumigant		
No Fumigant	NF	0.00
Methyl Bromide plus Chloropicrin	MB	1891.15
Methyl Iodide plus Chloropicrin	MIDAS	3976.62
Chloropicrin-250	PC250	662.50
Chloropicrin-400	PC400	1060.00
1,3-Dichloropropene plus Chloropicrin	TEL	619.88
1,3-Dichloropropene plus Chloropicrin and Metam Sodium	TELV	3438.01
Mulch		
Traditional Low Density Black on Black Polyethylene Mulch	LDPE	329.18
Smooth Low Density Black on Black Polyethylene Mulch	MS	599.50
High Barrier Black on Black Blockade Mulch	S	599.50
High Barrier Silver on Black Metalized Mulch	VIF-D	523.20

Table 2. Descriptive statistics and results of second-degree stochastic dominance analysis of gross revenue under different levels of risk aversion

Production Systems	Mean Revenues ($/acre)	Standard Deviation	Coefficient of Variation	SDSD Rank Neutral	Low	High
NF-LDPE	13,169.29	6,301.79	47.85	22	23	22
MB-LDPE	13,946.02	6,215.54	44.57	16	16	13
MIDAS-LDPE	14,957.18	7,108.77	47.53	7	7	18
PC250-LDPE	14,026.80	6,620.77	47.20	15	15	24
PC400-LDPE	12,837.13	6,347.51	49.45	25	25	28
TEL-LDPE	13,032.65	6,149.73	47.19	24	24	27
TELV-LDPE	15,133.67	7,438.73	49.15	6	6	23
NF-MS	13,630.10	6,573.80	48.23	19	19	19
MB-MS	16,023.13	6,932.77	43.27	2	2	3
MIDAS-MS	15,562.73	6,676.04	42.90	3	3	2
PC250-MS	15,368.05	6,825.18	44.41	4	4	7
PC400-MS	13,700.78	6,205.41	45.29	17	17	10
TEL-MS	15,281.94	7,328.65	47.96	5	5	20
TELV-MS	16,362.13	7,543.11	46.10	1	1	1
NF-S	12,773.70	6,441.04	50.42	26	26	26
MB-S	13,679.54	5,469.91	39.99	18	18	4
MIDAS-S	14,139.17	5,982.37	42.31	12	12	6
PC250-S	14,626.82	7,076.40	48.38	10	10	25
PC400-S	14,231.95	6,320.70	44.41	11	11	9
TELV-S	14,695.46	6,937.15	47.21	8	8	15
TEL-S	14,674.66	6,980.95	47.57	9	9	21
NF-VIF-D	13,374.51	6,579.48	49.19	20	20	16
MB-VIF-D	14,068.28	6,277.12	44.62	14	14	11
MIDAS-VIF-D	11,303.59	4,828.33	42.71	28	28	12
PC250-VIF-D	13,165.26	5,920.08	44.97	23	22	14
PC400-VIF-D	13,341.66	5,562.41	41.69	21	21	8
TEL-VIF-D	12,491.90	5,575.44	44.63	27	27	17
TELV-VIF-D	14,112.74	6,003.24	42.54	13	13	5

[a] Gross revenues and net returns were derived from enterprise budgets prepared for an acre of pepper farm operation. For purposes of this analysis, the yield results obtained from the 0.01 experimental plots were therefore extrapolated into one-acre operations to generate the gross revenue and net returns estimates.

NOTE:

1) Production systems are composites of fumigant and mulching method abbreviations described in Table 1. For example, NF-LDPE denotes a system whereby the NF fumigant method is complimented by corresponding use of the LDPE mulching method.

2) VIF-D for this study is by itself, a mulching system, not a composite of abbreviated terms.

Table 3. Descriptive statistics and results of second-degree stochastic dominance analysis of net returns under different levels of risk aversion

Production Systems	Fumigation & Mulching Cost per Carton ($)	Variable Cost per Carton ($)	Fixed Cost per Carton ($)	Mean Net Returns ($/acre)	Standard Deviation	Coefficient of Variation	SDSD Rank Neutral	SDSD Rank Low	SDSD Rank High
NF-LDPE	0.25	6.65	0.64	4,655.23	6,153.61	132.19	6	5	1
MB-LDPE	1.60	7.89	0.81	2,901.43	6,088.65	209.85	22	22	23
MIDAS-LDPE	2.91	9.11	0.98	1,135.69	6,943.71	611.41	26	26	28
PC250-LDPE	0.71	6.97	0.67	4,458.71	6,469.03	145.09	10	10	11
PC400-LDPE	1.10	7.61	0.79	3,159.98	6,189.29	195.86	21	21	22
TEL-LDPE	0.74	7.18	0.72	3,808.68	6,008.85	157.77	15	15	12
TELV-LDPE	0.86	6.95	0.66	4,904.94	7,255.20	147.92	4	4	20
NF-MS	0.45	6.76	0.65	4,659.09	6,416.99	137.73	5	6	3
MB-MS	1.56	7.52	0.73	4,025.34	6,800.26	168.94	13	13	21
MIDAS-MS	2.95	9.03	0.96	1,191.65	6,550.95	549.74	25	25	25
PC250-MS	0.83	6.85	0.64	5,052.67	6,686.91	132.34	3	3	4
PC400-MS	1.22	7.54	0.76	3,409.18	6,074.35	178.18	18	18	14
TEL-MS	0.81	6.86	0.64	5,078.73	7,155.63	140.89	2	2	16
TELV-MS	0.96	6.86	0.63	5,416.39	7,377.96	136.22	1	1	10
NF-S	0.48	6.98	0.70	4,072.14	6,275.09	154.10	12	12	7
MB-S	1.81	8.14	0.85	2,468.01	5,261.30	213.18	24	24	17
MIDAS-S	3.24	9.56	1.06	185.58	5,873.90	3,165.15	27	27	26
PC250-S	0.87	7.04	0.68	4,568.39	6,906.65	151.18	9	9	19
PC400-S	1.17	7.39	0.73	3,775.26	6,192.64	164.03	16	16	13
TEL-S	0.85	7.04	0.68	4,639.02	6,772.00	145.98	7	7	15
TELV-S	1.07	7.23	0.70	4,251.86	6,778.12	159.42	11	11	18
NF-VIF-D	0.40	6.77	0.66	4,578.52	6,416.92	140.15	8	8	2
MB - VIF-D	1.73	8.00	0.83	2,754.80	6,148.67	223.20	23	23	24
MIDAS-VIF-D	3.99	10.96	1.32	-1,711.87	4,738.76	-276.82	28	28	27
PC250-VIF-D	0.91	7.32	0.74	3,598.54	5,796.92	161.09	17	17	9
PC400-VIF-D	1.19	7.56	0.77	3,216.64	5,465.16	169.90	19	19	6
TEL - VIF-D	0.92	7.47	0.77	3,173.28	5,461.27	172.10	20	20	8
TELV- VIF-D	1.05	7.28	0.72	3,889.62	5,892.98	151.51	14	14	5

[a] Gross revenues and net returns were derived from enterprise budgets prepared for an acre of pepper farm operation. For purposes of this analysis, the yield results obtained from the 0.01 experimental plots were therefore extrapolated into one-acre operations to generate the gross revenue and net returns estimates.

[b] A carton is approximately equivalent to 28 lbs. of peppers.

NOTE:

1) Production systems are composites of fumigant and mulching method abbreviations described in Table 1. For example, NF-LDPE denotes a system whereby the NF fumigant method is complimented by corresponding use of the LDPE mulching method.

2) VIF-D for this study is by itself, a mulching system, not a composite of abbreviated terms.