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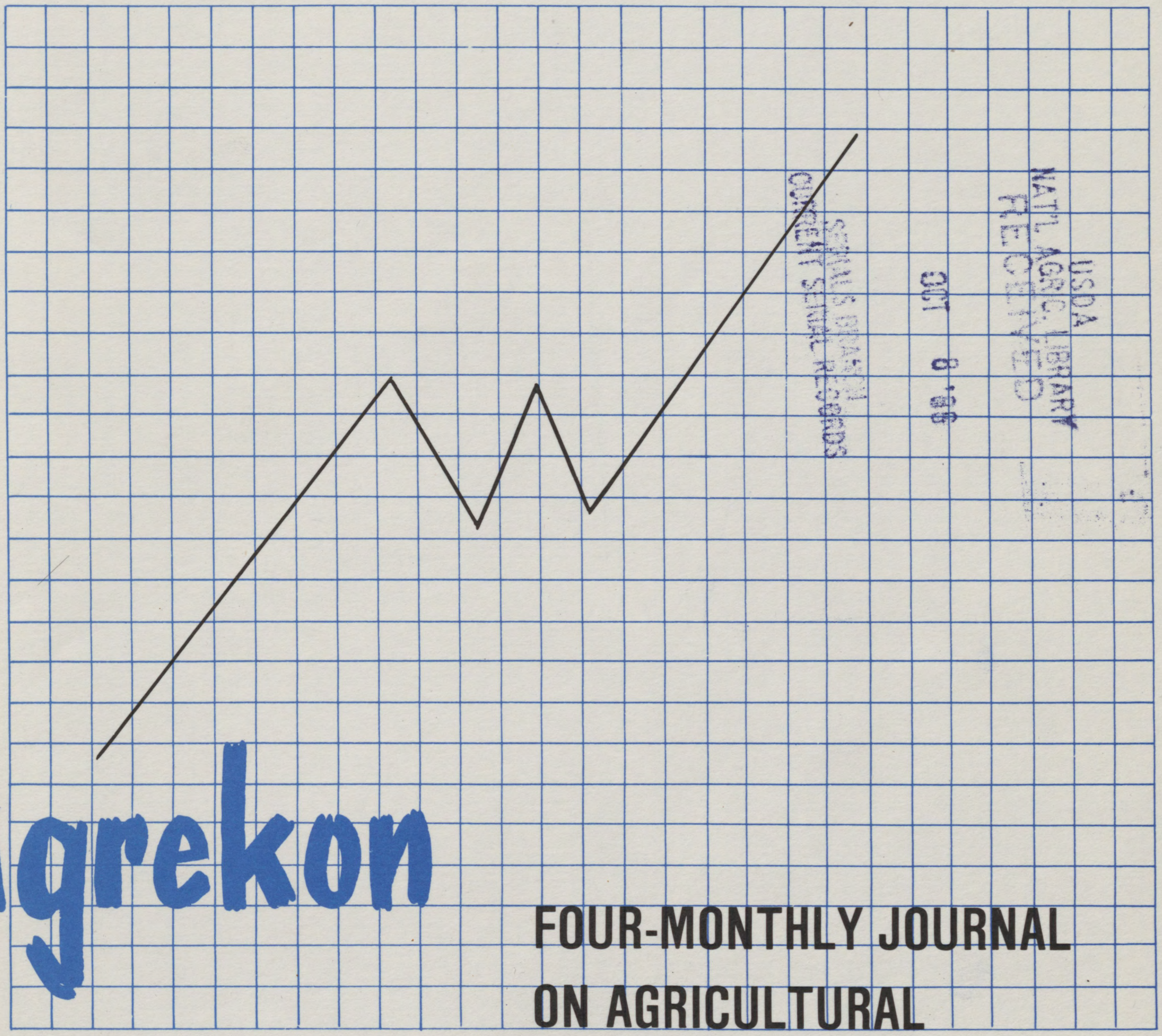

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A COMPARISON OF CERTAIN DECISION-MAKING TECHNIQUES UNDER RISK - AN EMPIRICAL INVESTIGATION OF MAIZE CULTIVAR SELECTION*

by J. VAN ZYL and J.A. GROENEWALD**

ABSTRACT

Results obtained with stochastic dominance, linear risk-programming (MOTAD), regression line evaluation and expected value calculations on maize-cultivar selection under varying circumstances were compared. Maize cultivar trial results of four localities over 14 years were used. Two levels of management were included.

Cultivar selections obtained by the different methods show a remarkable similarity. This is probably the result of the relative normal distribution in cultivar gross margins.

The largest single disadvantage of cultivar selection by adaptation regressions and expected value calculations is that it considers only the value of the gross margin and largely ignores the variance. This can lead to selection of ill-adapted cultivars. Stochastic dominance and MOTAD take both the expected value and variance into consideration. MOTAD is particularly useful as it invariably selects cultivar combinations.

INTRODUCTION

Various approaches have already been used in the study of decision-making under risk. The approach has to a large extent been determined by the nature of the specific problem being investigated. According to Samuelson (1965: 373), there are literally an infinite variety of models that can be used to study economic dynamics. The subject of portfolio selection under risk, especially under the headings of linear and non-linear mathematical programming, has lead to the development of a variety of mathematical algorithms (Anderson, Dillon & Hardaker, 1977).

According to Barnard and Nix (1979: 414), risk-decision techniques can be classified as follows in ascending order of practical usefulness in the 1980s: (1) Stochastic linear programming, (2) dynamic programming, (3) quadratic programming, (4) parametric programming and (5) various approaches to linear programming under risk. Anderson, Dillon and Hardaker (1977) also describe the uses and advantages of simulation in decision analysis.

In this study maize cultivars selected under varying conditions by stochastic dominance, linear programming under risk (MOTAD), regression line evaluation and the expected value method, are compared. Maize cultivar trial results of the Summer Grain Centre of the Department of Agriculture were used as a basis. Nine maize cultivars and four localities were included. Observations stretching over 14 years were obtained for each cultivar at each locality. The cultivars are SA4, SA5, SSM48, PNR88, NPP x K64R, A471W, PNR95, SR52 and R200, while the localities are the experimental farms of the Department of Agriculture at Potchefstroom, Bethlehem and Cedara and the experimental farm of the Oos-Transvaalse Koöperasie (OTK) at Bethal.

The chosen localities and cultivars vary considerably. Yields and associated gross margins were determined at each locality for every cultivar over 14 years with the given cultivation practices and optimal fertilisation levels according to the procedures of Van Zyl, Geerthsen and Groenewald (1985). The means, standard deviations and coefficients of variation of annual gross margins are shown in Table 1.

It appears that the stability of the gross margins, as measured by the coefficient of variation (C.V.), varies considerably between cultivars. The stability of a cultivar's gross margin also varies between localities and levels of management. Gross margins are less stable with average management than with above-average management because the decreases in mean gross margins are proportionally larger than the declines in standard deviations.

No relationship between the means and coefficients of variation of cultivar gross margins was generally found. The ranking order of cultivars according to value of the mean gross margin invariably varies with locality and level of management. Cultivar SR52 has, for example, the highest mean gross margin at Bethal with above-average management, but the lowest mean where the level of management is only average.

Mean cultivar gross margins per hectare for each situation and locality were compared by using the t test (Puri & Mullin, 1980). According to this, few cultivar means differ significantly. Only by way of exception, for example with A471W and NPP x K64R at Potchefstroom, differences between cultivar means are significant at the 1 per cent level. Generally only a few cultivar means differ significantly at the 10 per cent level. According to the F test variances in cultivar gross margin largely

*Based on a doctoral dissertation by J. van Zyl of the University of Pretoria

**University of Pretoria, March 1985

TABLE 1 - Mean, standard deviation and coefficient of variation of cultivar gross margins per hectare*

LOCALITY	Cultivar	Above-average management				Average management			
		Mean (R/ha)	S.D. (R/ha)	C.V. (%)	Std. error of mean (R/ha)	Mean (R/ha)	S.D. (R/ha)	C.V. (%)	Std. error of mean (R/ha)
BETHAL	SA4	474	394	83,1	105	336	326	97,3	87
	SA5	453	481	106,2	129	317	399	125,5	107
	SSM48	512	479	93,6	128	350	390	111,4	104
	PNR88	508	456	89,7	122	349	372	106,4	99
	NPP x K64R	483	487	100,8	130	318	392	123,2	105
	A471W	543	412	75,9	110	392	342	87,2	91
	PNR95	595	484	81,3	129	387	380	98,2	102
	SR52	641	715	111,5	191	305	490	160,7	131
	R200	566	487	86,0	130	377	389	103,3	104
POTCHEFSTROOM	SA4	364	232	63,4	62	259	193	74,5	52
	SA5	347	241	69,3	64	244	199	81,6	53
	SSM48	379	238	62,9	64	259	194	74,8	52
	PNR88	374	211	56,4	56	256	172	67,2	46
	NPP x K64R	142	158	111,0	42	61	127	207,3	34
	A471W	419	250	59,7	67	304	208	68,5	56
	PNR95	423	314	74,4	84	271	247	91,2	66
	SR52	344	440	128,1	118	131	302	231,0	81
	R200	389	225	57,8	60	253	180	71,0	48
BETHLEHEM	SA4	327	213	65,4	57	228	178	77,8	47
	SA5	312	186	59,7	50	215	154	71,7	41
	SSM48	337	204	60,5	55	225	166	73,8	44
	PNR88	333	240	72,0	64	223	196	87,9	52
	NPP x K64R	292	238	81,7	65	182	192	105,6	51
	A471W	381	282	73,9	75	272	234	85,9	63
	PNR95	378	298	78,7	80	236	234	99,0	63
	SR52	294	475	161,3	127	105	326	309,3	87
	R200	297	331	111,4	89	180	265	147,0	71
CEDARA	SA4	446	220	49,3	59	300	182	60,7	49
	SA5	433	223	51,4	60	289	185	63,9	49
	SSM48	493	249	50,5	67	323	203	62,8	54
	PNR88	490	237	48,3	63	322	193	60,1	52
	NPP x K64R	467	278	59,5	74	291	224	76,7	60
	A471W	512	257	50,2	69	354	213	60,2	57
	PNR95	584	280	47,9	75	363	220	60,6	59
	SR52	656	532	81,2	142	293	365	124,7	98
	R200	557	243	43,7	65	355	195	54,8	52

*Number of observations(N) in each case equals 14

follow the same pattern as differences between mean gross margins of cultivars.

The paucity of statistical significance in the means and variances of cultivar gross margins complicate the process of cultivar selection considerably. This was also an important contributing cause for the development of alternative methods for cultivar evaluation, for example the regression line evaluation technique by Robbertse (1969).

The normality and skewness of cultivar gross margins were analysed by using the Shapiro-Wilk test for examples with fewer than 50 observations (Sharpiro & Wilk, 1965) and the third order derived method.

According to the various tests, most of the observations were distributed relatively symmetrically. Positive skewness seems to predominate. Bethal is however the exception. Results with the Shapiro-Wilk test point at a large degree of normality in the distribution of cultivar gross margins. Cultivars however vary among themselves in respect of normality and skewness. The same cultivar also differs in this respect between localities and management levels. Cultivar selections can thus hardly be made with confidence.

The size of the expected gross margin, the stability of the gross margin as well as the probability of a certain outcome play a role in optimal cultivar selection under risk. A farmer's preferences again are mainly determined by his financial position. Methods relating the size and variation of cultivar yields to each other are thus needed to be able to choose between cultivars.

STOCHASTIC DOMINANCE

Various problems arise with the development of new technology in agriculture. The large number of individual decision-makers and the consequent differences in risk preferences cause the concept of one universally optimal choice not to be valid. The method of stochastic dominance may however effect

TABLE 2 - Stochastic dominant cultivars according to gross margin*

LOCALITY	Cultivar	Above-average management			Average management		
		1st degree	2nd degree	3rd degree	1st degree	2nd degree	3rd degree
BETHAL	SA4	X	X		X	X	
	SA5	X	X		X	X	
	SSM48	X	X		X	X	
	PNR88	X	X		X	X	
	NPP x K64R	X	X		X	X	
	A471W	X	X	X	X	X	X
	PNR95	X	X	X	X	X	
	SR52	X	X	X	X	X	
	R200	X	X		X	X	
POTCHEFSTROOM	SA4	X	X		X	X	
	SA5	X	X		X	X	
	SSM48	X	X		X	X	
	PNR88	X	X		X	X	
	NPP x K64R						
	A471W	X	X	X	X	X	X
	PNR95	X	X		X	X	
	SR52	X	X				
	R200	X	X		X	X	
BETHLEHEM	SA4	X	X	X	X	X	X
	SA5	X	X	X	X	X	X
	SSM48	X	X	X	X	X	X
	PNR88	X	X	X	X	X	
	NPP x K64R	X	X				
	A471W	X	X	X	X	X	X
	PNR95	X	X	X	X	X	
	SR52	X	X				
	R200	X	X		X	X	
CEDARA	SA4	X	X	X	X	X	
	SA5	X	X	X	X	X	
	SSM48	X	X		X	X	
	PNR88	X	X	X	X	X	
	NPP x K64R	X	X		X	X	
	A471W	X	X	X	X	X	X
	PNR95	X	X	X	X	X	
	SR52	X	X	X	X	X	
	R200	X	X	X	X	X	X

*X = Dominant cultivars

some reduction of alternative risky possibilities without needing a detailed knowledge of the utility functions of the population (Anderson, 1974; Anderson, Dillon and Hardaker, 1977 Ch 9).

Stochastic dominance analysis is based on a number of assumptions concerning risk preferences of decision-makers. The conceptual base is the assumption that decision-makers generally display risk aversion (Anderson, 1974). Choices between different risky prospects are now made according to one or other predetermined decision rule.

Anderson (1974) distinguishes between three concepts of stochastic efficiency. Each concept calls for more restrictive assumptions concerning risk preferences in order to further reduce the stochastic dominant set of plans. The more restrictive the assumptions, the thinner the ice and the less general are the results. For example, the assumptions whereupon stochastic efficiency of the second degree (SSD) is based, are more restrictive than those of the first degree (FSD), but less restrictive than the assumptions whereupon stochastic dominance of the third degree (TSD) are based.

Stochastic dominance is probably best determined by graphical methods if only a few continuous distributions are assessed. This is particularly useful when testing for FSD and SSD. Graphical methods of comparison are however not very convenient when testing for TSD (Anderson, 1974).

Even with high-speed computers problems are experienced, especially with the specification of the various cumulative probability distributions. Stochastic dominance tests require functions that are adequately specified by successive integrations of known distribution functions. An element of judgement and approximation is required to compare the derived functions irrespective of whether the method of integration is numerical or analytical in nature. Anderson (1974) hereupon proposed to approach each cumulative distribution function by a number of predetermined linear segments, each representing an equal interval of cumulative probability. The main advantage of this is that it is relatively simple to integrate a segmented linear function to define the SSD cumulative function, which then consists of quadratic segments which can also easily be integrated to define the subsequent TSD cumulative function. Another advantage of this approach is the relatively simple comparisons of pairs of functions. The mathematical background of this approach is discussed fully by Anderson (1974). The precision of approximation in this method is largely dependent on the number of linear segments used to present the cumulative frequency distribution curve. Therefore a balance must be maintained between precision and computational burden. A computer program in FORTRAN IV was developed by Anderson, Dillon & Hardaker (1977: 313-318) to conduct stochastic dominance testing by this method. The program is also used in this study for the determination of stochastic dominance.

According to Yassour, Zilberman and Rausser (1981), the technique of stochastic efficiency is particularly suited for optimal choice between alternative risky technologies. The technique was used with great success by Anderson (1974) in the selection of wheat cultivars, while Van Rooyen (1983: 32-35) and Van der Merwe (1982) discussed it as a potential future method for the evaluation of maize cultivars in South Africa. The method of stochastic dominance in the field of portfolio selection was also used by amongst others Porter and Gaumnitz (1972), Porter (1973), Anderson (1975), Anderson (1976), Kramer and Pope (1981) and Pope and Ziemer (1984).

Stochastic dominant cultivars of the first, second and third degree for the various localities and managerial levels are shown in Table 2.

According to Table 2, the sets of stochastic dominant cultivars of the first and second degree correspond completely. This may possibly be attributed to deviates that affect the shape of the cumulative probability distribution, or it may be the result of a limited number of observations whereby the interval method does not approach the distribution with adequate reliability. Van Rooyen (1983: 34) found this method to be sensitive to deviates and proposes that the highest and lowest yields should consistently be ignored. However, Anderson, Dillon and Hardaker (1977: 299) remark that cultivars should really be tested under extreme conditions precisely because high-yielding cultivars do worse than others under adverse conditions. Erroneous conclusions may thus follow if values are ignored.

Stochastic dominance testing of the first and second degree do eliminate some cultivars, and the effective set of cultivars is thus reduced. Third-degree stochastic dominance, however, produces the best results in respect of reduction of the stochastically dominant set of cultivars. This indicates that the cumulative gross margin distributions of the cultivars have more than one intersection.

LINEAR RISK PROGRAMMING

According to Barnard and Nix (1979: 429, 430), quadratic risk-programming produces the profit-maximizing combination or plan at any given level of variance (or risk). Alternatively it produces the plan with the smallest variance in profit (risk) for a given profit level.

The expected profit of subsequent combinations or plans can now be plotted against the variance thereof to determine an expected profit-variance (E-V) frontier. Such a frontier is depicted in Figure 1. The (E-V) frontier represents the effective set of risky alternatives or proposals. The selection of the optimal portfolio or combination out of this set of combinations on the (E-V) frontier is now determined by the tangent point of the decision-maker's utility curve and the (E-V) frontier. This optimal plan is shown in Figure 1.

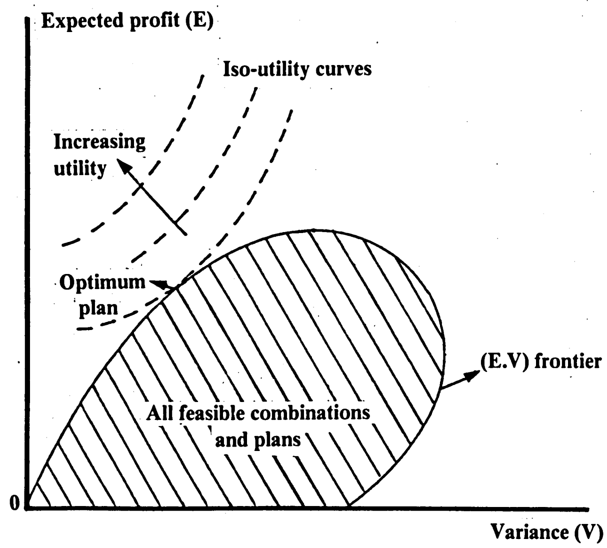

FIG. 1 - Graphic representation of the (E-V) frontier, utility curves and optimal plan

Practical applications of quadratic programming in agriculture are relatively limited. According to Barnard and Nix (1979: 432), insufficient data, which impede the composition of a variance-covariance matrix, is the major problem. Another disadvantage of the technique is the assumption of a normal distribution (or a call on the central limit theorem) that is certainly not always valid (Anderson, Dillon and Hardaker, 1977). The algorithm in quadratic programming also causes programming problems. The pros and cons associated with quadratic programming under risk, as well as that of expected profit/variance (E-V) analysis in general, has been discussed by various authors, including Feldstein (1969), Borch (1969) and Tsiang (1972).

Owing to the problems, which are experienced in particular with the algorithm in quadratic programming, various attempts have been made to develop linear programming models that consider the stochastic nature of activity profits in farm planning. These variations of linear programming include the incorporation of games theory in a programming formulation (Dorfman, Samuelson and Solow, 1958;

McInerney, 1969; Hazell, 1970), the use of constraints involving maximum permissible loss (Boussard and Petit, 1967; Boussard, 1971) and the use of the mean absolute deviation instead of the variance as measure of risk (Hazell, 1971). Chen and Baker (1974) illustrated how the (E-V) frontier of quadratic programming can be approximated by introducing a marginal risk constraint in a multidimensional linear programming model.

Hazell and How (1971) and Kennedy and Francisco (1974) discussed the similarities of the above-mentioned models in a farm planning context. These authors specifically showed that all these models, quadratic programming included, minimize the criterium of risk for a given set of possible levels of expected profit, subject to the usual farm constraints. The models differ mainly only in respect to the criterium of risk used.

According to Barnard and Nix (1979: 414), the mean absolute deviation approach of Hazell (1971) (MOTAD) has potentially the greatest application possibilities. From a decision-analysis point of view this approach is better than both the games theory and maximum permissible loss formulations (Anderson, Dillon and Hardaker, 1977: 207).

This method is an analogue to the quadratic risk programming approach, but does not use a non-linear programming algorithm. It also readily permits the inclusion of probabilities in outcomes.

Thompson and Hazell (1972: 506) used a Monte Carlo study to show that efficient plans generated with MOTAD largely correspond to (E-V) efficient plans obtained with the aid of quadratic programming. They also demonstrated that MOTAD is a satisfactory substitute for quadratic risk-programming and that, if probability distributions are not normal but skew, MOTAD might be better and thus preferable to quadratic programming. According to Day (1965: 739) crop yield distributions are usually not normal and curtosis and skewness should be considered in decision analysis under risk. In this light MOTAD appears to have certain application advantages over quadratic programming.

MOTAD has been used by a number of researchers for farm planning under conditions of risk. In addition to Hazell (1971), Schluter (1974) and Hazel and Scandizzo (1974) were early users of MOTAD. More recent researchers who followed the same approach, were Young (1979), Schurle and Erven (1979), Mapp *et al.* (1979), Brink and McCarl (1978), Hardin (1978) and Persaud (1980). The research work of Schurle and Erven (1979) in particular is important, since the sensitivity of the efficacious plans for farm planning was evaluated. The (E-V) frontier appears to be relatively sensitive to the omission of selected activities. The degree of sensitivity depends, however, on the nature of the differences in risk between the activities.

The mean absolute deviation method (MOTAD) has an advantage over stochastic dominance in that cultivar combinations are consistently considered. Cultivars on the (E-V) frontier form the risk-efficient set of cultivars (Hazell, 1971). The usefulness of MOTAD is however relatively limited if the covariance elements are high and positive.

Annual deviations from the mean gross margin of a cultivar under a specific set of circumstances, i.e. management level and locality, were calculated. A simplex tableau, with the minimization of annual deviations from the mean gross margin as objective, was then constructed for each set of circumstances. By equating the area under maize cultivation to 100 per cent, the percentage area to be planted with each cultivar to minimize the deviations from the mean

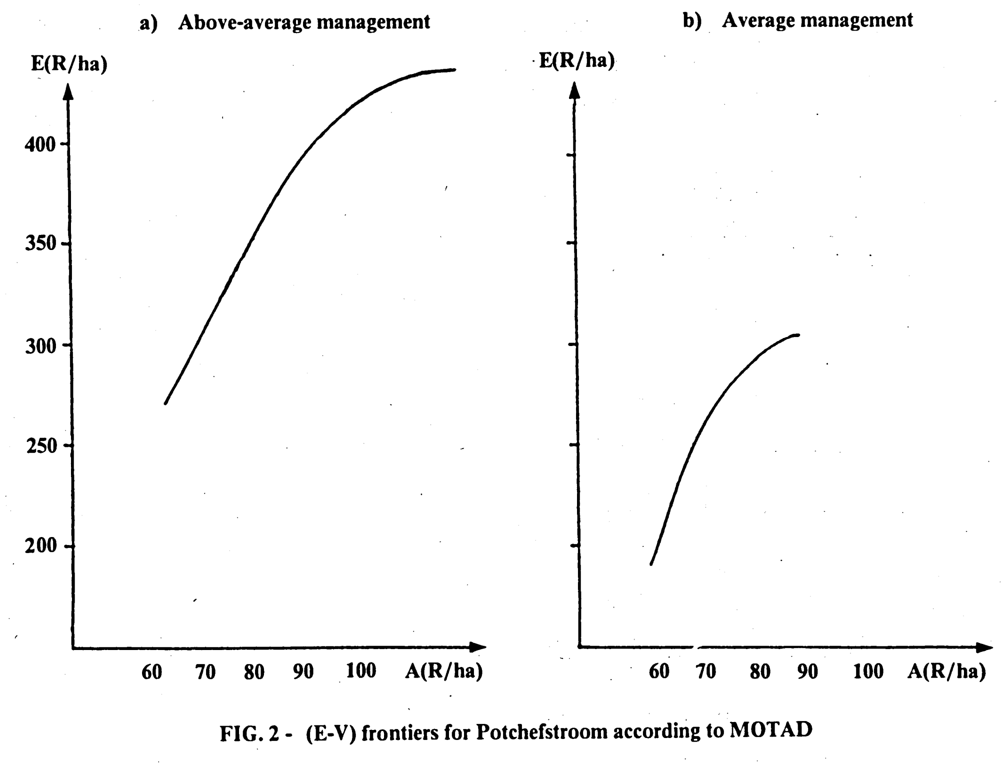

FIG. 2 - (E-V) frontiers for Potchefstroom according to MOTAD

TABLE 3 - Percentage acreage under a specific cultivar according to MOTAD at a specific locality and given management level

LOCALITY	MANAGEMENT	E (R/ha)	V (R/ha)	Cultivars (%) SA4	SA5	SSM48	PNR88	NPP x K 64R	A471W	PNR95	SR52	R200
BETHAL	Above-average	640	308	-	-	-	-	-	-	-	100,0	-
		620	267	-	-	-	-	-	-	43,5	56,5	-
		600	232	-	-	-	-	-	-	87,0	13,0	-
		580	212	-	-	-	-	-	27,5	72,5	-	-
		560	198	-	-	-	-	-	66,7	33,3	-	-
		540	185	-	-	-	-	-	99,4	-	-	-
		520	178	-	-	-	-	-	95,8	-	-	-
	Average	392	154	-	-	-	-	-	100,0	-	-	-
		380	150	-	-	-	-	-	96,9	-	-	-
		360	142	-	-	-	-	-	91,8	-	-	-
		340	134	-	-	-	-	-	86,7	-	-	-
POTCHEFSTROOM	Above-average	423	121	-	-	-	-	-	-	100,0	-	-
		420	109	-	-	-	-	-	75,0	25,0	-	-
		410	101	-	-	22,0	-	-	78,0	-	-	-
		390	92	-	-	70,7	-	-	29,3	-	-	-
		380	89	-	-	95,1	-	-	4,9	-	-	-
		370	86	-	-	90,6	7,3	-	-	-	-	-
		360	84	-	-	88,2	7,1	-	-	-	-	-
		330	77	-	-	88,0	6,6	-	-	-	-	-
	Average	303	87	-	-	-	-	-	100,0	-	-	-
		300	86	6,8	-	-	-	-	93,2	-	-	-
		290	82	10,3	-	19,2	-	-	70,5	-	-	-
		280	78	-	-	21,6	28,7	-	49,7	-	-	-
		270	75	-	-	0,2	70,0	-	29,8	-	-	-
		260	72	-	-	-	91,5	-	8,5	-	-	-
		250	69	-	-	-	97,7	-	-	-	-	-
		240	66	-	-	-	93,7	-	-	-	-	-
BETHLEHEM	Above-average	381	114	-	-	-	-	-	100,0	-	-	-
		370	104	-	-	25,0	-	-	75,0	-	-	-
		350	84	-	-	70,5	-	-	29,5	-	-	-
		330	73	-	31,4	66,6	-	-	1,9	-	-	-
		310	69	-	36,9	57,8	-	-	-	-	-	-
		290	64	-	34,5	54,1	-	-	-	-	-	-
	Average	272	95	-	-	-	-	-	100,0	-	-	-
		220	59	-	38,1	61,4	-	-	-	-	-	-
		200	54	-	34,6	55,8	-	-	-	-	-	-
		180	48	-	31,2	50,2	-	-	-	-	-	-
		160	43	-	27,7	44,6	-	-	-	-	-	-
CEDARA	Above-average	656	206	-	-	-	-	-	-	-	100,0	-
		640	184	-	-	-	-	-	-	22,2	77,8	-
		620	157	-	-	-	-	-	-	50,0	50,0	-
		600	130	-	-	-	-	-	-	77,8	22,2	-
		580	105	-	-	-	-	-	-	85,7	-	14,3
		560	97	8,2	-	-	-	-	-	46,6	45,2	-
		540	91	23,2	-	-	1,2	-	-	37,1	-	38,5
		520	86	26,5	-	-	22,2	-	-	27,9	-	23,4
	Average	363	85	-	-	-	-	-	-	100,0	-	-
		350	75	15,2	-	-	-	-	-	42,2	-	42,5
		330	68	27,6	-	-	34,2	-	-	23,0	-	15,1
		310	62	36,7	-	-	62,3	-	-	-	-	-
		290	58	34,3	-	-	58,3	-	-	-	-	-
		270	54	31,9	-	-	54,3	-	-	-	-	-
		250	50	29,6	-	-	50,2	-	-	-	-	-
		230	46	27,2	-	-	46,2	-	-	-	-	-

cultivar gross margins at a given level of income, are determined. The cultivars on the (E-V) frontier were determined by varying the given level of income. The results for Bethal, Bethlehem, Cedara and Potchefstroom are shown in Table 3. The assumption throughout is that maize is the only crop planted.

From Table 3 it is clear that the (E-V) effective set of cultivars contains more than one cultivar under most circumstances. Only NPP x K64R does not form part of the (E-V) effective set at least once. (E-V) frontiers can be constructed for each set of circumstances by using Table 3. An example of the (E-V) frontiers for Potchefstroom is shown as a graph in Figure 2.

Figure 2 clearly illustrates the declining variance (A) in the diminishing expected gross margins (E). At high values of E, A initially declines slower so that the (E-V) frontier is curved. However, when the acreage under maize is smaller than 100 per cent, A declines at a constant tempo so that the (E-V) frontier is linear.

REGRESSION LINE EVALUATION

In the early stage of development of a crop, differences between cultivars can be considerable, and cultivar means for environments can in such conditions yield useful and stable evaluation criteria. However, if differences between cultivars become smaller over time, usually because of breeding, genotype-environment interaction tends to play a more important role relative to pure cultivar differences (Geerthsen, undated). The usefulness and repeatability of cultivar means as evaluation criteria will therefore decline.

Robbertse (1969) shows that stable genotype environment interactions over years do not occur in maize yields in the RSA. The interaction cannot therefore satisfactorily be reduced by area classification. Robbertse (1973: 64) thereafter identified factors that describe a geographical locality and may influence maize cultivar yields. In all cases, mean trial yield showed the highest correlation with a specific cultivar yield, while correlations between locality characteristics and cultivar yield were smaller (Robbertse, 1970). It was furthermore found that mean trial yield explains 89 per cent of variation in cultivar yield and that the relationship between the two variables is almost without exception linear. These linear regression graphs vary relatively little over time. It points to a high degree of reliability of the method.

Two computer programs, developed by the Department of Genetics at the University of Pretoria in PL/1, execute the regression line graph technique physically. The first program calculates the regression formula and related statistics, while the second program controls the graph plotter and plots the regression line with confidence curves at a 5 per cent level of significance. The confidence curves are a visual representation of the D^2 value; this is the numerical variance of the calculated values around the regression line and thus the variance of the error in the analysis of the variance. The D^2 value represents the best criterion of stability (Eberhard and Russel, 1966, as quoted by Geerthsen, undated) and is therefore, apart from the regression line itself, the most important result for cultivar evaluation.

Regression lines with gross margins as input data were calculated for the various cultivars under different circumstances. Results are shown in Table 4.

COMPARISON OF RESULTS

Different cultivars are selected by various cultivar evaluation methods in the different situations as "best" cultivar in a specific set of circumstances. Table 5 shows the cultivars selected by the various methods in each situation. In the case of the expected value and regression line evaluation the three cultivars with the highest gross margin in the specific environment were consistently chosen. In the case of MOTAD all the cultivars that form part of the (E-V) frontier were taken, while stochastic dominance of the third degree was used to determine stochastic dominant cultivars. Resistance to pests and other adaptation aspects were not considered.

Table 5 shows that selected cultivars generally show a high degree of correspondence irrespective of the selection method. This phenomenon can largely be the result of the relative normality of cultivar gross margins.

Stochastic dominant and (E-V) efficient cultivars correspond largely. Only the number of cultivars in the efficient set differs occasionally and the one group is always a subset of the other.

TABLE 4 - Statistics referring to some regression lines under varying circumstances

Management	Cultivar	Regression equation*	Degrees of freedom	F value	P value	R^2 value
Above-average management	SA4	$Y^1 = 60{,}578 - 0{,}207X$	54	590,0	0,000 0	0,916 2
	SA5	$Y^1 = 12{,}922 - 0{,}135X$	54	457,3	0,000 0	0,894 4
	SSM48	$Y^1 = 32{,}986 - 0{,}080X$	54	1 042,0	0,000 0	0,950 7
	PNR88	$Y^1 = 38{,}631 - 0{,}102X$	54	1 356,6	0,000 0	0,980 7
	NPP x K64R	$Y^1 = 60{,}024 - 0{,}059X$	54	321,4	0,000 0	0,856 2
	A471W	$Y^1 = 77{,}474 - 0{,}106X$	54	812,9	0,000 0	0,937 7
	PNR95	$Y^1 = 41{,}666 + 0{,}050X$	54	1 017,8	0,000 0	0,949 6
	SR52	$Y^1 = 219{,}958 + 0{,}629X$	54	679,4	0,000 0	0,962 5
	R200	$Y^1 = 15{,}739 + 0{,}011X$	54	678,8	0,000 0	0,926 3
Average management	SA4	$Y^1 = 50{,}096 - 0{,}163X$	54	593,4	0,000 0	0,916 6
	SA5	$Y^1 = 14{,}548 - 0{,}087X$	54	469,4	0,000 0	0,896 8
	SSM48	$Y^1 = 27{,}073 - 0{,}049X$	54	1 044,9	0,000 0	0,950 9
	PNR88	$Y^1 = 31{,}105 - 0{,}070X$	54	1 335,0	0,000 0	0,961 1
	NPP x K64R	$Y^1 = 49{,}638 - 0{,}047X$	54	314,1	0,000 0	0,953 3
	A471W	$Y^1 = 69{,}755 + 0{,}054X$	54	828,1	0,000 0	0,938 8
	PNR95	$Y^1 = 26{,}282 + 0{,}045X$	54	980,6	0,000 0	0,947 8
	SR52	$Y^1 = 178{,}943 + 0{,}404X$	54	621,1	0,000 0	0,920 0
	R200	$Y^1 = 9{,}752 + 0{,}021X$	54	656,4	0,000 0	0,924 0

*X = Mean yield of all the cultivars in the trials

Y^1 = Deviation in cultivar yield from the mean yield of all the cultivars

TABLE 5 - Selected cultivars for different environments

	MANAGE-MENT	Method of selection: MOTAD**	Stochastic dominance	Regression line evaluation*	Expected value*
CEDARA	Above average	SR52; PNR95; A471W	A471W: PNR95; SR52	SR52; PNR95; R200	SR52; PNR95; R200
CEDARA	Average	A471W	A471W	A471W; PMR95; R200	A471W; PNR95; R200
BETH-LEHEM	Above average	PNR95; A471W; SSM48; PNR88	A471W	PNR95; A471W; R200	PNR95; A471W; R200
BETH-LEHEM	Average	A471W; SA4; SSM48; PNR88	A471W	A471W; PNR95; SSM48	A471W; SA4; SSM48
POTCHEF-STROOM	Above average	A471W; SSM48; SA5	SA4; SA5; SSM48; A471W; PNR95	PNR95; A471W; R200	A471W; PNR95; SSM48
POTCHEF-STROOM	Average	A471W; SSM48; SA5	SA4; SA5; SSM48; A471W	A471W; PNR95; PNR88	A471W; PNR95; SA4
BETHAL	Above-average	SR52; PNR95; R200; SA4; PNR88	SA4; SA5; PNR88; A471W; PNR95; R200	SR52; PNR95; A471W	SR52;PNR94; R200
BETHAL	Average	PNR95;SA4; PNR88; R200	PNR95; R200	A471W; PNR95; R200	PNR95; A471W; R200

* In decreasing order of magnitude and preference
** Selected cultivars are not necessarily simultaneously part of the (E-V) frontier (see Table 3)

Although the regression line graphs select cultivars that are frequently the same as those with the highest expected gross margin, poorly adapted cultivars like SR52 at Potchefstroom and R200 at Bethlehem also appear in the efficient set.

The biggest single disadvantage associated with cultivar selection by regression line evaluation and expected value, as shown in Table 5, is that only the magnitude of the gross margin is taken into account. It can thus happen that two cultivars have the same expected gross margin, but that the variation in gross margin differs largely. If two cultivars have equal expected gross margins, the rational producer will select the cultivar with the smallest variation.

In contrast to this, stochastic dominance and MOTAD criteria thoroughly consider both the magnitude and variation in gross margins. In consequence of the selected stochastic dominant cultivars in Table 5, it appears that stochastic dominance has great applicability in maize cultivar selection and in risky decision-making in general. In this instance, where cultivar gross margins are relatively normally distributed, MOTAD supplies useful selections in that combinations of cultivars are consistently chosen. However, the high and positive covariance elements restrict the usefulness of MOTAD.

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