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A STOCHASTIC OPTIMUM PROPORTION UNDER SHARED SYSTEM OF SOLE CROPS

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C O N T E N T S

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SUMMARY

Intercropping systems are often compared with sole crops. However, when responses on both components in a two-crop system are required, a shared sole crop system is also considered as an alternative system for comparing the productivity under intercrops. The productivity of the shared system depends on the proportion of area allotted to two sole crops. A method for choosing this shared proportion of the two sole crops in the same plot in a stochastic optimal way is presented in this paper.

1. Introduction

Intercropping is a system of growing two or more crop species (in separate rows) in conjunction on the same piece of land. Such systems have been practised for long by the farmers of tropics (Aiyer 1949, Willey 1979). Sole crops are often used for comparing the productivity of intercrop. But the sole crops can yield on only one type of crop species if used as an alternative to intercrop. However, when yields on both crops are required, a system called 'shared system of two sole crops' has been considered by Rao and Willey (1980). Under shared system of two sole crops a (continuous) portion of the plot is sown under one crop while the remaining part is allotted to the second crop. Thus such a shared system consists of two sole systems arranged together in a plot. Shared sole crop system differs from intercrop where the crop species are sown in alternate rows (or in alternate sets of few rows) in conjunaction. A pictorial presentation of the plot (say of unit area) under three systems appears as below.

Sorghum/Pigeonpea	Sole crops		Shared sole crops
Intercrop	Sorghum	Pigeonpea	Sorghum Pigeonpea
S P S P S P S P	S S S S S S S S	P P P P P P P P	S S S P P P P P
S P S P S P S P	S S S S S S S S	P P P P P P P P	S S S P P P P P
S P S P S P S P	S S S S S S S S	P P P P P P P P	S S S P P P P P
S P S P S P S P	S S S S S S S S	P P P P P P P P	S S S P P P P P

where S and P stand for the two species, say, sorghum and pigeonpea respectively, for example.

It may be noted that the area s for a crop, say S may vary under shared system and hence a class of shared systems would be generated over the values of s where $O<s<1$. $s=O$ or 1 results in a sole crop system. Rao and Willey (1980) obtained the shared proportion s such that the shared system gives the yields in proportion to that of intercrop component yields. But such a choice of s depends on behaviour (competition) of the crop species in intercrop and may not be a production (productivity) efficient choice if crops are sown under shared sole system, where the competition is almost absent. Therefore, the need of obtaining s in an optimal sense arises and this paper attempts to develop a method to choose an optimal s.

Intercropping systems are practised in environments where weather/climate is unpredictable or, poses some risks for crop during crop growth. For comparing intercropping systems Rao and Willey (1980) obtained the probabilities of obtaining a specified net return under various systems. Such probabilities for getting specified yield on one component or both were considered by Pearce and Edmonson (1982) and avoided the effects of prices of crops. In a more general framework Anderson (1974) had used the concept of stochastic dominance or risk efficiencies. We therefore, use a similar stochastic approach by evaluating the probability of getting specified yields on component crops under shared system for determining optimum shared proportion s. The comparison of an intercropping system with an optimal shared sole system using joint probabilities would be most relevant.

In section 2, we give a method of determining optimal s and illustrate its computation in section 3.

2. Stochastic Optimum Shared Proportion.

Under sole system it is reasonable to assume the distribution of yields as normally distributed. Let the yield of crop s be normally distributed with the mean μ_s and variance σ^2_s while that of crop P with mean μ_p and σ^2_p. If a segment of an area s of a unit area plot be allotted to sole S, then under the shared system, the yield on crop S, say Y_s will follow $N(s\,\mu_s,\ s^2\sigma^2_s)$ and yield on crop P, say Y_p will be $N(s'\,\mu_p,\ s'^2\sigma^2_p)$, $s' = 1-s$. Further, let the minimum specified yields required under the shared system be $p\mu_s$ on crop S and $q\,\mu_p$ on crop P. The probability of obtaining at least these yields together is given by

$$Pr = \text{Prob}[Y_s \geq p\mu_s,\ Y_p \geq q\mu_p] \tag{1}$$

Further, under the shared system, the yields of the two sole crops S and P are independent. Therefore, above probability simplifies as below

$$Pr = Prob\,[Y_s > p\mu_s]\; Prob[Y_p > q\mu_p]$$
$$= Prob[s(\mu_s + \sigma_s Z) > p\mu_s]\; Prob[\bar{s}\,(\mu_p + \sigma_p Z) > q\mu_p]$$
$$= (1 - \Phi((p/s - 1)C_s))(1 - \Phi((q/\bar{s} - 1)C_p)) \quad (2)$$

where Z stands for the standard normal variable and $C_s = \mu_s/\sigma_s$, $C_p = \mu_p/\sigma_p$

$$\Phi(x) = \int_{-\infty}^{x} \phi(t)dt = \int_{-\infty}^{x} (1/\sqrt{2\pi})\exp(-t^2/2)dt$$

(standard normal probability integral)

The quantity Pr is a function of s for given values of p,q,s,C_s and C_p. The stochastic optimum shared proportion s_0 $(0 < s_0 < 1)$ is defined as the one which maximizes the probability Pr. Thus for a given set of crops $(\mu_s, \sigma_s, \mu_p, \sigma_p)$, optimum s_0 vary with the desired proportions p and q of sole yields required under shared system. The nature of the function Pr of s for few selected values of p, q, μ_s, μ_p, σ_s and σ_p are presented in Figure 1. This figure indicates the existence of optimum s unless the values of p and q are too high.

INSERT FIGURE 1

Differentiating Pr with respect to s and equating to zero results as below

$$dPr/ds = -pC_s\,\phi((p/s-1)C_s)(1-\Phi((q/\bar{s}-1)C_p))/s^2$$
$$+\ qC_p\,\phi((q/\bar{s}-1)C_p)(1-\Phi((p/s-1)C_s))/\bar{s}^2 = 0$$

or,

$$s = 1/(1+R^{1/2}) \tag{3}$$

where

$$R = q\,C_p\,\phi((q/\bar{s}-1)C_p)(1-\Phi((p/s-1)C_s))/(pC_p\,\phi((p/s-1)C_s)$$
$$(1-\Phi((q/\bar{s}-1)C_p)))$$

The solution of (3) can be obtained iteratively. The neighbourhood of optimal s successfully be located by exploring the range (0,1) for s.

3. An illustration

Consider the following information on two sole crops of sorghum and pigeonpea.

	Sole crops	
	Sorghum	Pigeonpea
mean	4103	1226
standard deviation	1622	609

These means and standard deviations are computed from the distribution of means (of replications) of the crops over 36 environments (consisting of 9 locations and 4 years) from trials administered by ICRISAT, Patancheru, Andhra Pradesh.

For some selected values of p and q, Table 1 presents the iterative solution of equation (3).

Table 1.

Optimum values of s in few

(S~N(4103, 1622) and P~N(1226, 609))

p=0.25				p=0.50			
q=.20		q=.40		q=.20		q=.60	
Itrn	Value	Itrn	Value	Itrn	Value	Itrn	Value
8	52	34	41	23	.67	32	.49
9	53	35	42	24	66	33	48
10	53	36	42	25	66	34	.48

Itrn = Iteration number

We made the application of the above method for obtaining stochastic optimal s for several sets of data with a view to compare with related intercrops.

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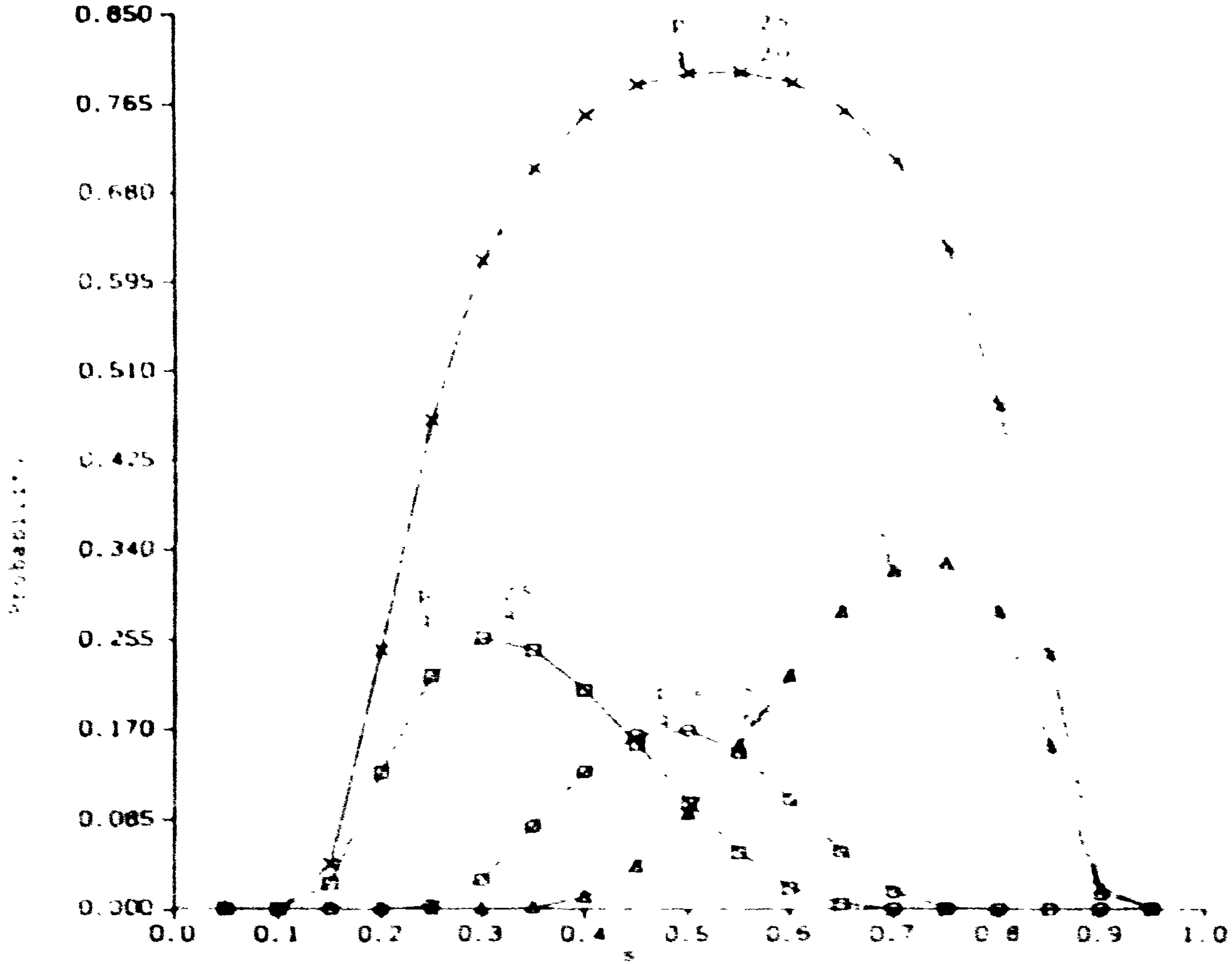

Figure 1. Probabilities of ... shared ... system as a function of shared area s for selected values of p, q, and ...

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