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Application of Goal Programming on Yield Optimization of Selected Agricultural Crops

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ABSTRACT: A study was carried out in the field of agriculture to optimize the yield of the crops by the application of goal programming. From the review of literature, it can be seen that the application of optimization models in agriculture is comparatively less in scientific world. Hence, crops such as chilli and string bean were selected for the study, assigning with different levels of spacing and fertilizer under monocropping and intercropping systems. Yield was optimized with application of input cost such as weeding, land preparation, irrigation and planting materials to find out the optimum yield over recommended yield through goal programming. From this optimization model, plant number and planting material cost were optimized by 14.6 % and 14.3 %, respectively. Total recommended and optimized yield of green chilli under monocropping were 58 ton/ha and 51.25 ton/ha, respectively. Similarly, under intercropping, total recommended and optimized yield of green chilli were 28 ton/ha and 21.25 ton/ha, respectively. However, the recommended and optimized yield of string bean were 17.28 ton/ha and 14.9 ton/ha respectively under each system due to equal number of the population maintained in both systems.

KEYWORDS: Agriculture, Crops, Goal programming, Optimization, Yield.

I. INTRODUCTION

The scope of agriculture is the utilization of resources in the most efficient manner. In the collaboration between operation research and agriculture lays a big step up of exploitation in upcoming epoch (Shivatharsinii *et al.* 2016). From the review of literature, it can be seen that the application of optimization models in agriculture is comparatively less and done by Muncan, undated; Qingzhen *et al.* 1991 and Sirotenko and Romanenkov, undated). Linear (Anon. undated, Scarpari and Ferreira de Beauclair, 2010) and multi-objective (Berbel, 1989) programming have been used in agriculture for optimization. Hence, the study was carried out in yield optimization of chilli and string bean in alliance with goal programming for a new way for the multiple objective aspirations (Adekanmbi and Olugbara, 2015) by goal programming model. In the real world there are goals, to be achieved simultaneously or to be reached in priority order such as linear programming which is used for single goal. In our study, there are multiple goals that would be optimized by goal programming (Janova, 2014). The basic design on the research is that the yield optimization would cover under category of cropping system such as mono and intercropping by using the crops chilli and string bean. Monocropping is a cropping pattern where planting one variety of plants. Inter cropping is the other type of cropping pattern where one kind of plants planted within another kind of plants (Rani and Rao, 2012). The suggested OR model tries to predict optimum yield with different levels of spacing and organic fertilizer under inter cropping and mono cropping system (Mansourifaret *et al.* 2013). In the present world, since farmers are coming from poor backgrounds, they seek out financial predicament throughout their life span (DOA, undated). Due to this, cost optimization is significantly important to find a higher yield with lower cost. Hence, the proposed OR model is much more helpful to minimize the

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cost. Objective of the study is to optimize the yield of the crops for different levels of fertilizer and spacing under both intercropping and monocropping system.

II. MATERIALS AND METHODS

Crops such as string bean and chilli were selected for the study. Different levels of organic fertilizer (F_1 -control; F_2 -450 g/6 m²; F_3 -1,200 g/6 m²; F_4 -1,800 g/6 m²), spacing (string bean: S_1 -90 cm×30 cm; S_2 -100 cm×35 cm; S_3 -110 cm×40 cm) (chilli: S_1 -45 cm×60 cm, S_2 -100 cm×35 cm; S_3 -55 cm×70 cm) and cropping systems (M_1 -monocropping of chilli and string bean; M_2 - Intercropping of chilli and string bean) were taken as treatments for the optimization. Field plot was assigned in randomized complete block design with dimension of 3 meters length and 2 meters width. Total planting areas was assessed to be 648 square meters. Projected areas for each crop were 432 square meters. Projected areas for each system of intercropping and monocropping were 216 square meters. Around 5 kg of *azospirillum* bio-fertilizer was mixed with 100 kg super compost mixture containing 30 kg super compost and 70 kg reddish soil is recommended for one acre of field (VDF, undated). Expected yield and planting material (PM) cost were determined based on the required number of planting materials. Yield and inputs of crops were taken as objectives and constraints, respectively. Objectives were formulated with the application of the following constraints in the experiment (Table 1).

Model application for optimization

Optimization model was applied on recommendation of the agriculture. Objectives were taken with the application of constraints in the experiment.

Table 1: Variable Description

Variables	Crops	Cropping systems	i	j
x_{ij11}	Chilli	Monocropping	Fertilizer $i=1,2,3,4$	Spacing $j=1,2,3$
x_{ij22}	Stringbean	Monocropping		
x_{ij13}	Chilli	Intercropping		
x_{ij23}	Stringbean	Intercropping		

Table 1 shows the variables of two crops: chilli and string bean, cropping system: monocropping and intercropping, levels of fertilizer: $i=1,2,3,4$ and levels of spacing: $j=1,2,3$.

Let x_{ij11} be the number of chilli plants in monocropping in i^{th} fertilizer j^{th} spacing level. $i = 1,2,3,4$ and $j = 1,2,3$
 x_{ij22} be the number of string bean plants in monocropping in i^{th} fertilizer j^{th} spacing level. $i = 1,2,3,4$ and $j = 1,2,3$
 x_{ij13} be the number of chilli plants in intercropping in i^{th} fertilizer j^{th} spacing level. $i = 1,2,3,4$ and $j = 1,2,3$
 x_{ij23} be the number of string bean plants in intercropping in i^{th} fertilizer j^{th} spacing level. $i = 1,2,3,4$ And $j = 1,2,3$

Objective 1: Maximize the expected yield of chilli in monocropping (Eq.1)

$$\max Z_1 = 2,700 * \sum_{i=1}^4 \sum_{j=1}^3 x_{ij11} \geq 302,000$$

Where,

Z_1 is the expected yield of chilli, such that x_{ij11} be the number of plants in a plot with the i^{th} fertilizer in j^{th} spacing

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Objective 2: Maximize the expected yield of string bean in monocropping (Eq.2)

$$\max Z_2 = 972 * \sum_{i=1}^4 \sum_{j=1}^3 x_{ij22} \geq 186,624$$

Where,

Z_2 is the expected yield of string bean, such that x_{ij22} be the number of plants in a plot with the i^{th} fertilizer in j^{th} spacing

Objective 3: Maximize the expected yield of string bean and chilli in intercropping (Eq.3)

$$\max Z_3 = 2,700 * \sum_{i=1}^4 \sum_{j=1}^3 x_{ij13} + 972 * \sum_{i=1}^4 \sum_{j=1}^3 x_{ij23} \geq 489,024$$

Where,

Where Z_3 is the expected yield of chilli and string bean, such that x_{ij13} and x_{ij23} be the number of plants in a plot with the i^{th} fertilizer in j^{th} spacing

Constraint 1: Total cost (Eq.4)

$$4 * \left(\sum_{i=1}^4 \sum_{j=1}^3 x_{ij11} + \sum_{i=1}^4 \sum_{j=1}^3 x_{ij13} \right) + 6 * \left(\sum_{i=1}^4 \sum_{j=1}^3 x_{ij22} + \sum_{i=1}^4 \sum_{j=1}^3 x_{ij23} \right) \leq 11,040$$

Total cost obtained should be limited for Rs 11,040. This constraint should be satisfied because cost optimization is much important.

Constraint 2: Total chilli plant available (Eq.5)

$$\left(\sum_{i=1}^4 \sum_{j=1}^3 x_{ij11} + \sum_{i=1}^4 \sum_{j=1}^3 x_{ij13} \right) \leq 1,034$$

Total number of chilli plant should be limited to 1,034.

Constraint 3: Total number of string bean available (Eq.6)

$$\left(\sum_{i=1}^4 \sum_{j=1}^3 x_{ij22} + \sum_{i=1}^4 \sum_{j=1}^3 x_{ij23} \right) \leq 1,152$$

Total number of string bean should be limited to 1,152.

Constraint 4: Total fertilizer available (Eq.7)

$$0 * (x_{1j11} + x_{1j22} + x_{1j13} + x_{1j23}) + 32,400 * (x_{2j11} + x_{2j22} + x_{2j13} + x_{2j23}) + 64,800 * (x_{3j11} + x_{3j22} + x_{3j13} + x_{3j23}) + 97,200 * (x_{4j11} + x_{4j22} + x_{4j13} + x_{4j23}) \leq 97,200$$

Total fertilizer available for total plants should be less than 97,200 g. Maximum fertilizer available according to recommended level is 97,200 g.

Constraint 5: Number of string bean plants in monocropping and intercropping (Eq.8)

$$x_{ij22} = x_{ij23}$$

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Constraint 6: Total number of plants in each plot

(Eq.9 – Eq.56)

$$\begin{array}{llll}
 25 \leq x_{1111} \leq 28, & 12 \leq x_{1211} \leq 15, & 12 \leq x_{1311} \leq 15, & 25 \leq x_{2111} \leq 28, \\
 12 \leq x_{2211} \leq 15, & 12 \leq x_{2311} \leq 15, & 25 \leq x_{3111} \leq 28, & 12 \leq x_{3211} \leq 15, \\
 12 \leq x_{3311} \leq 15, & 25 \leq x_{4111} \leq 28, & 12 \leq x_{4211} \leq 15, & 12 \leq x_{4311} \leq 15, \\
 15 \leq x_{1122} \leq 18, & 12 \leq x_{1222} \leq 15, & 12 \leq x_{1322} \leq 15, & 15 \leq x_{2122} \leq 18, \\
 12 \leq x_{2222} \leq 15, & 12 \leq x_{2322} \leq 15, & 15 \leq x_{3122} \leq 18, & 12 \leq x_{3222} \leq 15, \\
 12 \leq x_{3322} \leq 15, & 15 \leq x_{4122} \leq 18, & 12 \leq x_{4222} \leq 15, & 25 \leq x_{4322} \leq 15, \\
 13 \leq x_{1113} \leq 16, & 03 \leq x_{1213} \leq 06, & 03 \leq x_{1313} \leq 06, & 13 \leq x_{2113} \leq 16, \\
 03 \leq x_{2213} \leq 06, & 03 \leq x_{2313} \leq 06, & 13 \leq x_{3113} \leq 16, & 03 \leq x_{3213} \leq 06, \\
 03 \leq x_{3313} \leq 06, & 13 \leq x_{4113} \leq 16, & 03 \leq x_{4213} \leq 06, & 03 \leq x_{4313} \leq 06, \\
 15 \leq x_{1123} \leq 18, & 12 \leq x_{1223} \leq 15, & 12 \leq x_{1323} \leq 15, & 15 \leq x_{2123} \leq 18, \\
 12 \leq x_{2223} \leq 15, & 12 \leq x_{2323} \leq 15, & 15 \leq x_{3123} \leq 18, & 12 \leq x_{3223} \leq 15, \\
 12 \leq x_{3323} \leq 15, & 15 \leq x_{4123} \leq 18, & 12 \leq x_{4223} \leq 15, & 12 \leq x_{4323} \leq 15
 \end{array}$$

Each category of plants should be within range maximum and minimum number of plants that should be allocated within a plot.

Other constraints

$$x_{ij11}, x_{ij22}, x_{ij13}, x_{ij23} \geq 0 \quad (\text{Eq.57})$$

$$x_{ij11}, x_{ij22}, x_{ij13}, x_{ij23} - \text{integers} \quad (\text{Eq.58})$$

The Excel software was used as a tool to solve the goal programming model. The solver function is very useful to elucidate the goals. In model solving procedure, each goal was satisfied to get success model. Condition of the model is that each yield obtained by our model is greater than the recommended level.

III. EXPERIMENTAL RESULTS

Optimized planting materials for each spacing and fertilizers were given in table 1. From this optimization model, plant number and planting material cost was reduced by 14.6% and 14.3%, respectively. Total plant number was reduced by about 12.5% in mono cropping and by about 17.4 % in intercropping. Required number of planting materials of about 15.70% and 13.54% were reduced for of chilli and string bean, respectively after model application. About 14.56% of the planting material cost was saved from total cost after model application (Table 2). Planting materials cost of about 15.70% and 13.54% were reduced for of chilli and string bean, respectively. About 14.35% of the planting material cost was saved from total cost. Average yield about 15.7% and 13.54 % were optimized for chilli and string bean respectively. Total yield about 15.08% was optimized. Required number of planting materials of chilli was reduced by 11.6% and 24.1% in monocropping and intercropping, respectively. Required number of planting materials was reduced by 13.5% in both mono cropping and intercropping system.

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Table 2: Inputs of experiment in both chilli and string bean after model application

	Attributes	Chilli			String bean			Total %
		Recommendation	After model	% of reduction	Recommendation	After model	% of reduction	
Overall	Plant numbers	2064.0	1740	15.7	2304	1992	13.5	14.6
	PM Cost	4128.0	3480	15.7	6912	5976	13.5	14.3
	Yield (kg)	1857.6	1566	15.7	746.5	645.4	13.5	15.1
Mono	Plant numbers	1392.0	1230	11.6	1152	996	13.5	12.5
	PM Cost	2784.0	2460	11.6	3456	2988	13.5	12.7
	Yield (kg)	1252.8	1107	11.6	373.3	322.7	13.5	12.1
Inter	Plant numbers	672	510	24.1	1152	996	13.5	17.4
	PM Cost	1344	1020	24.1	3456	2988	13.5	16.5
	Yield (kg)	604.8	459	24.1	373.3	322.7	13.5	20.1

Note: PM: planting materials; recommended average yield of chilli and string bean per plant was 900g and 324g, respectively. From optimized number of plants, yield and planting material cost were calculated. Cost of chilli and string bean per plant was Rs.2 and 3, respectively. From optimized number of plants, cost was calculated. Expected sales price of chilli and string bean per kg was Rs.50 and 70, respectively.

Table 2 shows the details of attributes of plant numbers, planting materials cost and yield for recommended, after model application and % of optimization.

IV. CONCLUSION

From this experiment, it can be concluded that required number of planting materials and cost of planting materials were optimized by this optimization model. By considering the input cost, model was run to obtain the optimized yield. Farmer can get the optimum yield and safe income by this reduced number of planting materials.

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