MODELLING APPROACH TO OPTIMIZE SULPHUR FERTILIZATION IN IRRIGATED SUNFLOWER UNDER SEMI-ARID CONDITIONS IN NORTH-WEST INDIA

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ABSTRACT
Sulphur fertilization assumes substantial influence in improving the yield and quality of oilseed crops. The relationship between sunflower seed yield and sulphur dose applied was determined using quadratic model and the economically optimum sulphur dose was calculated via marginal analysis for yield maximization and profit over fertilizer cost. Economically optimum dose of sulphur for sunflower was found to be 32.99 and 38.95 kg/ha under semi-arid irrigated conditions during 2008 and 2009, respectively. Over-fertilized condition of S for maximum output did not bring out any significant advantage viewing almost identical seed yield both at physical and economic optimum of S indicating a saving of S from 2.8 to 4.0 kg/ha.

Key words: Economically optimum, Marginal analysis, Quadratic function, Sulphur dose, Sunflower seed yield

INTRODUCTION
India, one of the major oilseed growing countries of the world is unable to meet its own oil needs and vast sums of foreign exchange are spent every year to import edible oils. The greatest challenge before India in the future, therefore, is to be self-sufficient in vegetable oils to feed burgeoning population, improve living standards and ever increasing industrialization. Apart from major plant nutrients (N, P and K), sulphur (S) fertilization assumes greater significance for improved seed yield and quality produce (Hussain et al., 2011; Kumar et al., 1981; McGrath and Zhao, 1996 and Wani et al., 2001). In general, sulphur demand of oilseed crops is higher than those of cereal crops as they contain more S containing compounds (Scherer, 2001). Approximately 12 kg S is required to produce one ton of oilseed and the response of oilseed crops to S application ranges between 15 to 62 kg/kg S applied (Hegde and Sudhakar Babu, 2009) depending on the inherent fertility status and S source being used. For every tonne of S added through fertilizers, twice the amount is being taken up by the crops resulting in net depletion of the soil S (Tandon and Messick, 2007). Therefore, the mining of soil S reserves should be minimized for sustaining the soil fertility and crop productivity.

There is no doubt that the increased use of inputs induces an upward shift in production function to the extent that a technological change is embodied in them. But, it is economically and environmentally important to supply sufficient amount of fertilizer to the crop plants for exploiting the desired yield potential. Optimum fertilizer application in the recent years has gained substantial importance to ensure a high quality product, optimum yield, more net profit and less environmental pollution (Alivelu et al., 2006 and Belanger et al., 2000). Contrary to this, sometimes over fertilization and insufficient fertilization application lead to economic losses (Grant, 2006). Therefore, it becomes imperative to fine tune fertilizer application as per the crop demand to make it more judicious, environmental friendly and economical.
LEGUME RESEARCH

(Antoniadou and Wallach, 2002 and Henke et al., 2007).

Sunflower, an oilseed crop holds a great promise with chances of area expansion and horizontal intensification for improving oilseed production to meet out the shortage of edible oils in the country. But, inadequate and/or imbalanced use of fertilizers has been identified as one of the critical constraints for sunflower production. Global reports of S-deficiency and consequent crop response in oilseeds in general and sunflower in particular has led to find out the effect of sulphur fertilization on sunflower yield particularly under irrigated conditions in intensive cropping system of Punjab state representing SAT region where the commercial sunflower cultivation is only limited to spring season. Therefore, the present investigation was planned to find out the cost effective economic optimum dose of sulphur for sunflower in North Western region of India.

MATERIALS AND METHODS

The field experiments were conducted at the Oilseeds Research Farm of Punjab Agricultural University, Ludhiana, Punjab to study the influence of levels and sources of sulphur on the productivity of sunflower under semi-arid irrigated conditions during spring 2008 and 2009. The treatment combinations consisted of four sources of S, viz., ammonium sulphate, single super phosphate, gypsum and elemental sulphur and three levels of S (0, 20 and 40 kg/ha). The experiment was laid out in randomized block design with three replications. The soil of the experimental site was loamy sand (Typic Ustipsament) in texture, slightly alkaline in nature, low in organic carbon (0.23%) and available nitrogen (115 kg/ha), medium in available phosphorus (11.3 kg/ha) and potassium (165 kg/ha) and low in available sulphur (7.1 ppm) content. After thorough seed bed preparation, seeds of sunflower hybrid PSH 569 were sown at a spacing of 60 x 30 cm in the first fortnight of February by dibbling two to three seeds per hill. Later on, the plots were hand thinned to one plant per hill when the plants were at the four to six-leaf stage. The treatment plots were uniformly fertilized with 60 kg N, 30 kg P₂O₅, and 30 kg K₂O/ha taking into consideration the contribution of sulphur sources towards nitrogen and phosphorus nutrition. Half dose of N in the form of urea/diammonium phosphate, full dose of P (DAP), K (muriate of potash) and S as per treatments were applied at the time of sowing while remaining N was top dressed at 30-35 days after planting with first irrigation. Standard cultural practices as per state recommendations were followed till the harvest of the crop. At maturity, sunflower heads were harvested from the net plot, dried and threshed manually to determine the seed yield which was then expressed in kg/ha.

To know the yields-fertilizer relationship, linear, quadratic, square root and mitscherlich models were tried. It was observed that the relationship between seed yield obtained and quantity of S applied was determined using quadratic model.

\[ Y = a + bX + cX^2 \]

where, \( Y \) = seed yield in kg/ha,
\( X \) = quantity of S applied in kg/ha and
\( a \), \( b \) and \( c \) are the constants.

In the test analysis, only the seed yield of sunflower was considered as the dependent variable and the expected yields were worked out accordingly. The estimated maximum yield values in the model were obtained by finding the value of ‘X’ by equating the first derivatives of the reaction equations to zero and replacing the same with whatever the figure stated above is obtained. On the other hand, economic optimum dose was determined via marginal analysis. The sulphur fertilizer dose where the Marginal Revenue (MR) is equal to Marginal Cost (MC) was designated as the economically optimum dose. Total revenue (TR) function was calculated by multiplying production function with unit product price (\( P_y \)). Accordingly, TR function was calculated as;

\[ TR = P_y \cdot Y = P_y (a + bX + cX^2) \]

\[ MR = \frac{dTR}{dX} = bP_y + 2cP_yX \]

Total cost (TC) function was obtained by multiplying the price of the input used with the input amount. Accordingly, TC function is calculated as;
Marginal cost (MC) function was calculated by differentiating the first order derivative of TC function. Maximum yield is achieved when the marginal production (MP) is equated to zero. MP can be worked out by differentiating the first order derivative of production function Y. MP is calculated as:

\[ MP = \frac{\partial Y}{\partial X} = b + 2cX \]

The average unit price of sulphur (irrespective of the source) was taken as Rs 23/kg. However, the market price of sunflower seed was Rs 24 and 22.15/kg during 2008 and 2009, respectively.

RESULTS AND DISCUSSION

The best fit response equation as explained by quadratic model to study the sulphur management in sunflower under semi-arid irrigated conditions is given in Table 1 and 2. The test analysis indicated that more than 55 and 89 per cent of the total variation in sunflower seed yield was due to application of S during 2008 and 2009, respectively. Based on the regression analysis, the maximum possible yield potential that can be exploited with respect to the amount of sulphur applied is shown in Figure 1 and 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>Standard error</th>
<th>t-value</th>
<th>p-value</th>
<th>R²-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2212.0</td>
<td>72.09</td>
<td>30.63</td>
<td>0.000</td>
<td>0.554</td>
</tr>
<tr>
<td>X</td>
<td>12.312</td>
<td>6.56</td>
<td>1.88</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>X²</td>
<td>-0.172</td>
<td>0.135</td>
<td>-1.27</td>
<td>0.025</td>
<td></td>
</tr>
</tbody>
</table>

FIG 1: Predicting sunflower yield at different levels of sulphur under semi-arid irrigated conditions using the regression equation (2008)

FIG 2: Predicting sunflower yield at different levels of sulphur under semi-arid irrigated conditions using the regression equation (2009)

The costlier fertilizers, poor resource base as well as lack of knowledge and aptitude of cultivators towards using fertilizers uptil the recommended level still arise the question that upto what extent fertilizer application should be made to achieve the sustainable and profitable production level rather than using fertilizers to target maximum possible yield potential without keeping in view the economic returns and impairing environmental quality. Therefore, it becomes imperative to consider whether the additional income (MR) brought out by each unit of sulphur added covers the risk of additional fertilizer cost (MC) or not. In this context, additional income obtained from the production amount (X) by adding each additional unit of input used (X) is taken into consideration. The ratio of the additional change observed in Y product to additional change in X factor and the ratio of X factor price to Y factor price should be equal at the point where MR is equal to MC for a profitable production to determine the economically optimum sulphur dose.

To meet the objective of the study, the relationship between the amount of sulphur applied and sunflower yield obtained for the year 2008 was worked out using a quadratic equation as under:

\[ Y = -0.172X^2 + 12.312X + 2212 \quad R^2 = 0.554 \]

TR function was obtained by multiplying the production function for the year 2008 with the
product price (Rs 24/kg) as; TR = -4.13X² + 295.49X + 53088

MR function was obtained by first order derivative of TR function as; MR = -8.26X + 295.49 TC function was obtained by multiplying the price of the input used (Rs 23/kg) with the input amount as; TC = 23S. Marginal cost (MC) function was obtained by differentiating the first order derivative of TC function as; MC = 23

Optimum level of S was determined by equating MC with MR as; 23 = -8.26X + 295.49, and X = 32.99 kg/ha was found to be the economical optimum dose of sulphur for sunflower. However, the maximum seed yield due to sulphur application, i.e., physical optimum dose can be achieved by the equating MP to zero as; MP = \frac{\partial Y}{\partial X} = b + 2cX = 0, 12.312 + 2*(-0.172)X = 0, and S = 35.79 kg/ha. The optimum and maximum seed yield recorded with application of sulphur was 2430 and 2432 kg/ha (Table 3).

When the same calculations were made for the year 2009, the production function is obtained as; Y = -0.117X² + 10.044X + 2401 R² = 0.892

TR function (P_X Y) and MR function (which is the first derivative of TR function), were calculated as TR = -2.81X² + 241.06X + 57624 and MR = -5.62X + 241.06. Similarly, TC function (P_X X) and MC function (which is the first derivative of TC function), were calculated as TC = 22.15X and MC = 22.15. With these calculation and equations, the economic optimum sulphur dose for sunflower for the year 2009 was calculated as (22.15 = -5.62X + 241.06) 38.95 kg/ha. The maximum yield recorded with sulphur application was determined by equating MP to zero (10.044 + 2*(-0.117)X = 0) and was found to be 42.92 kg/ha for the year 2009. The seed yield of 2615 and 2617 kg/ha was obtained when sulphur was applied at its optimum and maximum output levels, respectively (Table 3).

The data presented in Table 3 further revealed that over fertilized condition of sulphur did not show any significant yield advantage and the sunflower seed yield obtained with physical optimum and economic optimum of S was observed to be almost identical during both the years. Thus, there can be a saving of sulphur from 2.8 to 4.0 kg/ha without any reduction in seed yield of sunflower.

Based on the results, it can be concluded that economic optimum yield of sunflower could be obtained with the application of sulphur between 32.99 to 38.95 kg/ha. Profit can be increased by decreasing the S dose from maximum yield to the economically optimum dose.

TABLE 2: Estimation of the model determining the relationship between the sulphur dose applied and sunflower yield obtained during spring 2009

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficients</th>
<th>Standard error</th>
<th>t-value</th>
<th>p-value</th>
<th>R²-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2401.0</td>
<td>27.71</td>
<td>93.88</td>
<td>0.000</td>
<td>0.892</td>
</tr>
<tr>
<td>X</td>
<td>10.044</td>
<td>2.52</td>
<td>3.98</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>X²</td>
<td>-0.117</td>
<td>0.052</td>
<td>-2.24</td>
<td>0.021</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 3: Response function, optimum dose and seed yield in relation to sulphur management in sunflower

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Response equation</td>
<td>Y = -0.172S² + 12.312S + 22</td>
<td>Y = -0.117X² + 10.044X + 2401</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S dose (kg/ha)</td>
<td>32.99</td>
<td>35.79</td>
<td>38.95</td>
<td>42.92</td>
</tr>
<tr>
<td>Seed yield (kg/ha)</td>
<td>2430</td>
<td>2432</td>
<td>2615</td>
<td>2617</td>
</tr>
</tbody>
</table>

REFERENCES


Grant C. (2006). Enhancing nitrogen use efficiency in dry land cropping systems on the Northern Great Plains. 18th World Congress of Soil Science, Philadelphia, USA.


