**Productivity and Profitability correlation and regression and response curve of Sesame (*Sesamum indicum* L.) as influenced by Integrated Nitrogen Management and Sulphur Fertilization in semi-arid condition of Rajasthan**

**ABSTRACT**

A field experiment was conducted under loamy sand soil during *kharif* 2020 and 2021 at Agronomy farm, S.K.N. College of Agriculture, Jobner. The treatments comprising seven integrated nitrogen management (control, 100% RDN, 100% RDN through FYM, 100% RDN through vermicompost, 50% RDN + 50% N through FYM, 50% RDN + 50% N through vermicompost and 50% N through FYM + 50% N through vermicompost) and four levels of sulphur (0, 20, 40 and 60 kg/ha) assigned respectively to main and sub plots were replicated thrice in split plot design. Result showed that different treatments of integrated nitrogen management had significant effect on yield, net returns and sulphur use efficiency of sesame. Application of 50% RDN + 50% N through vermicompost (N5) and 50% RDN + 50% N through FYM (N4), were the most superior and equally effective treatments in enhancing these parameters among all the treatments. Fetching the maximum net returns of  52872/ha with B: C ratio of 2.96, application of 50% RDN + 50% N through vermicompost was recorded as the most remunerative treatment and found at par with 50% RDN + 50% N through FYM which gave net returns of  51281/ha with B: C ratio 3.11. Applications of 100% RDN and 50% N through FYM + 50% N through vermicompost were noted to be the next superior and equally effective treatments in improving yield and net returns in sesame. Results further revealed that progressive increase in level of sulphur up to 40 kg/ha resulted significant improvement on productivity and profitability of sesame over preceding levels. Significant improvement in net returns (46914/ha) and B: C ratio (2.78) was also obtained up to this level of sulphur fertilization. Being at par with 60 kg/ha, sulphur fertilization at 40 kg/ha also fetched 7.9 and 38.7 per cent more net returns over 20 kg/ha and control, respectively. Based on the response studies, application of sulphur at 49.04 kg/ha was the optimum level of S for sesame. 50% RDN + 50% N through vermicompost was also found best for agronomic efficiency (AE) and apparent recovery (RE) of applied S (3.11 kg seed/kg S; 3.44%). Maximum AE, RE and physiological efficiency (PEs) were obtained with 20 kg S/ha.

Keywords: Sesame, Productivity, Sulphur, Profitability and Integrated nitrogen management

**Introduction**

Sesame (*Sesamum indicum* L.) is an important edible oilseed crop that may be produced in a broad range of climates, from semi-arid tropics to sub-tropics along with groundnut and rapeseed-mustard. Sesame oil is one of the oldest oils known to human being (Prasad, 2017). Sesame is known as the "Queen of Oilseeds" due to its high oil content, delectable nutty scent, and flavour and is considered a health food in Asian nations. Oil content in sesame ranges from 43 to 52 percent, with protein level ranging from 18 to 20 percent. Protein, carbohydrates, vitamins and minerals are abundant in sesame cake or meal, which is obtained as a by-product of the oil milling industry (Ca and P). Because of its high methionine content, sesame cake is a good nutritional feed for cattle, particularly milch animals and a component of poultry feed. Sesame cake contains 6.0-6.2 percent nitrogen, 2.0-2.2 percent phosphorus and 1.0-1.2 percent potassium and may be used as manure in soil. The oil cake is an edible cake high in the amino acids methionine, cystein, arginine and tryptophan.

In world, sesame is farmed on 12.82 million hectares area with a production of 6.549 million tonnes (FAOSTAT, 2019). India, Sudan and Myanmar are the top three producers, accounting for around 60% of global output. The overall acreage of our country was 15.8 lakh hectares with an overall production of 7.92 lakh tonnes (DAC&FW, 2021). Gujarat, Madhya Pradesh, Rajasthan and Uttar Pradesh accounted for 1.10 million hectares in India (79.1 percent of the national acreage). The crop covered 3.05 lakh hectares in Rajasthan and produced 1.25 lakh tonnes with a productivity of 417 kg/ha (Anonymous 2020-21). Due to low and scarce rainfall, crop production on marginal and sub-marginal soils of poor fertility, poor agronomic techniques and inadequate or non-use of fertilizers, sesame productivity in Rajasthan is very low in contrast to global and national levels. It is critical to fertilize the crop properly for harvesting its production potential. The requirement for integrated nutrient management, which includes the use of both organic and inorganic fertilizers to provide superior nutrients to agricultural plants (Shaikh *et al*., 2010). The integrated nitrogen management approach was established to reduce over exploitation of soil fertility and plant nutrient, allowing soil health and plant nutrient to remain at optimal levels. Nitrogen is a fundamental element that promotes vegetative development and is one of the vital nutrients. It is a component of protoplasm and plays a key function in several physiological processes in plants. Nitrogen is an important component of molecules such as amino acids, porphyrin, nucleic acids, flavin, pyrimidine, purine, nucleotides, enzymes and co-enzymes, and is fundamental to their action. Its absence slows growth and root development, causes leaves to turn yellowish or light green, and accelerates maturation.

Different organic sources of nitrogen, such as farm yard manure, vermicompost and chicken manure, as well as inorganic sources such as urea, di ammonium phosphate and ammonium sulphate are used. The organic matter added is an indispensable component of soil and plays an important role in maintenance and improvement of soil fertility and productivity. Proper management of these will make it possible to increase the efficiency of added nutrients. Integrated nitrogen management continues to spread out importance to maintain soil health for sustainable production of good quality sesame. Farm yard manure improves the soil structure and is used as a natural fertilizer in farming. It increases the soil capacity to hold more water and nutrients. Vermicompost has high porosity and moisture-holding capability; promote pathogen-free plant development while also increasing microbial activity. Inorganic fertilisers have less nitrogen and other macro and micro nutrients than farm yard waste.

Sulphur is an essential plant nutrient and oilseed crops require more sulphur than cereals since their oil storage organs are primarily sulphur-rich proteins. Sulphur deficiency is known to impair N metabolism in plants as well as the production of S-containing amino acids, resulting in lower seed and oil yields. Sulphur is required for the creation of chlorophyll, which allows plants to create starch, sugar, oils, lipids, vitamins and other molecules through photosynthesis. Sulphur application appears to be extremely profitable and appears to be crucial for increasing crop yield, according to research conducted in various sections of the nation. In Rajasthan's light grained soil, available sulphur is often less than 5-10 ppm. Each unit of sulphur added to such soils can increase the supply of edible oil by 3.5 units (Tandon, 1995).

**MATERIALS AND METHODS**

The experiment was conducted at Agronomy farm, S.K.N. College of Agriculture, Jobner during two consecutive *kharif* seasons of 2020 and 2021, respectively. Geographically, Jobner is situated 45 km west of Jaipur at 260 05' North latitude, 750 28' East longitude and at an altitude of 427 metres above mean sea level. The area falls in Agro-Climatic Zone-IIIA (Semi-Arid Eastern Plain Zone) of Rajasthan. The climate of this region is typically semi-arid which is characterized by extremes of temperature both in summer and winter with low rainfall and moderate humidity. The maximum temperature in summer goes as high as 45o C, whereas, the minimum temperature in winter falls as low as 1-20 C. During the experimentation period, the minimum and maximum temperatures ranged from 10.5 to 25.40 C and 30.2 to 37.60 C during *Kharif* 2020 and 13.0 to 25.70 C and 30.1 to 38.20 C during *Kharif* 2021, respectively. The average relative humidity ranged from 43 to 87 per cent and 50 to 89 per cent during *Kharif,* 2020 and *Kharif,* 2021, respectively. The average sunshine hours ranged between 3.0 to 9.3 hours/day during 2020 and 2.3 to 9.9 hours/day during 2021. Rainfall received during the crop period was 252.2 and 236.1 mm during 2020 and 2021, respectively. In order to evaluate the physico-chemical properties, soil samples from 0-15 cm depth were taken from five random spots of the experimental field prior to layout and representative composite sample was prepared by mixing and processing of all soil samples together. The homogeneous composite soil sample was subjected to mechanical, physical and chemical analysis. It is apparent from data that soil of the experimental field was loamy sand in texture, alkaline in reaction, poor in organic carbon (0.23-0.27%), low in available nitrogen (130.08-132.25 kg/ha) and medium in phosphorus (15.41-16.22 kg/ha), potassium (147.24-148.09 kg/ha) and sulphur (9.20-9.24 mg/kg) content.

 The treatments comprising seven integrated nitrogen management-control (N0), 100% RDN (N1), 100% RDN through FYM (N2), 100% RDN through vermicompost (N3), 50% RDN + 50% N through FYM (N4), 50% RDN + 50% N through vermicompost (N5) and 50% N through FYM + 50% N through vermicompost (N6) and four levels of sulphur (0, 20, 40 and 60 kg/ha) assigned respectively to main and sub plots were replicated thrice in split plot design. Sesame cultivar ‘RT-351 was sown with standard package of practices. Application of farm yard manure and vermicompost was applied 15 days before sowing as per treatment. Sulphur was applied and mixed into the soil through gypsum as per treatment before sowing. Sowing was done with ‘*pora*’ method in rows spaced at 30 cm with average depth of 4 cm and seed rate of 4 kg/ha. All the plant protection measures were adopted to take health crop. At maturity stage, after leaving two rows on each side as well as 50 cm along the width of each side, a net plot area of 3.0 m x 1.8 m was harvested separately for recording the yield attributes and yields. The harvested material was tied and tagged and kept on floor for sun drying. After complete drying, the produce of each plot was weighed on electric balance and the threshing was done manually by inverting and shaking of stalks. Sesame seeds were cleaned by winnower and yield was recorded. Stalk yield was obtained by subtracting seed yield from total biomass yield. Yield was expressed in kg/ha. The harvest index was calculated by economic yield by biological yield and expressed in percentage. Net returns were calculated based on seed and stalk yield and prevailing market price of sesame seed. Agronomic efficiency (AE), recovery efficiency (RE) and physiological efficiency were calculated by standard formulae. All the observation during individual years as well as in pooled analysis were statistically analyzed for their test of significance using the *F*-test (Gomez and Gomez, 1984). The significant of difference between treatment means were compared with t critical difference at 5 % level of probability.

**RESULTS AND DISSCUSSION**

**Productivity:** Integrated nitrogen management and sulphur fertilization significantly increased sesame seed yield, under semi-arid condition in both the years (Fig. 1). The highest seed yield (826 and 772 kg/ha) was recorded in N5 followed by N4 (782 and 731 kg/ha) which was significantly higher than N1 treatment (761 and 716 kg/ha) during 2020 and 2021, respectively. The seed yield of sesame was at par with all other treatments in which integrated nitrogen was applied but significantly higher over control. The results obtained may be due to integration of chemical fertilizer along with organic manures which fulfill the nutrient requirement of the crop in the initial stage of crop growth. At subsequent stages, decomposition and mineralization of organic sources released the macro and micro nutrients from vermicompost and FYM by soil organism which favored to nutritional requirement, sustained sesame crop and thereby resulting in higher yields (Krishnaprabu 2013). Stalk yield of sesame was significantly influenced with application of different treatments of integrated nitrogen management and sulphur fertilization (Fig. 2). Application of 50% RDN + 50% N through vermicompost exhibited significantly the highest stalk yield of 2456 kg/ha, 2425 kg/ha followed by 50% RDN + 50% N through FYM 2349 kg/ha and 2309 kg/ha during 2020 and 2021. Sulphur fertilization at 40 kg/ha recorded significantly higher seed, stalk and biological yield (752, 2270 and 3022 kg/ha and 704, 2222 and 2926 kg/ha during 2020 and 2021) of sesame than 20 kg/ha and control. However, it was found at par with 60 kg S/ha. Gopinath *et al.* (2011) also suggested that only organic nutrients do not increase the yield of sesame. Integration of organic and inorganic sources of plant nutrient elements results in more uptake of them as compared to sole use of organic or inorganic ones. This may be due to the fact that the balanced and combined use of various plant nutrient sources results in proper absorption, translocation and assimilation of those nutrients, ultimately increasing the dry-matter accumulation and nutrient contents of sesame and thus showing more uptake of elemental nutrients.

**Profitability:** Net returns and B: C ratios in sesame were significantly improved due to all the integrated nitrogen management treatments (Table 1). Fetching the highest net returns of ₹ 52872/ha with B: C ratio of 2.96, application of 50% RDN + 50% N through vermicompost was the most remunerative treatments. Application of 50% RDN + 50% N through FYM and 100% RDN provided the additional net returns of ₹ 26157 and 25650/ha with B: C ratio of 3.11 and 3.20, respectively and thus proved as the next better and statistically similar treatments. Application of 100% RDN through FYM and 100% RDN through vermicompost also increased the net returns by 54.0 and 45.5 per cent over control and attained B: C ratio of 2.49 and 2.17. This was mainly due to higher seed yield and lower treatment cost than FYM and vermicompost alone or in combination. The higher net returns and B: C ratio recorded under these superior treatments can be explained easily with the corresponding higher seed yields under these treatments. The lowest seed yield due to lesser nitrogen and other major nutrients in control treatment was ultimately reflected in lowest net returns (₹ 25124/ha) and B: C ratio (2.15). These results are in cognizance with the findings of Choudhary *et al.* (2017) in sesame. Being at par with 60 kg/ha, application of 40 kg S/ha provided significantly higher net returns of ₹ 46624/ha with B: C ratio of 2.80. Sulphur fertilization at 60 kg/ha provided additional net returns of ₹ 3430 and 13290/ha over 20 kg S/ha and control and attained the maximum B: C ratio (2.78). As net return is computed by multiplying the seed yield and their sale prices and subtracting the total cost of cultivation including treatment cost, thus higher net return could be primarily due to higher seed and stalk yields with comparatively lesser additional cost of sulphur compared to additional yield and returns obtained under this treatment. Similar findings have also been reported by Singh and Mann (2007), Bhosale *et al*. (2011) and Dash *et al.* (2013) in sesame.

**Correlation and Regression:** Immense increase in crop dry matter as well as yield determining parameters of sesame having significant and positive correlation with seed yield (Table 3) further confirms findings of present investigation. Regression studies also indicated that a unit increase in crop dry matter, capsules/plant, seeds/capsule and test weight increased the seed yield of sesame by 1.93, 25.98, 21.86 and 0.33 kg/ha, respectively (Table 3). The results are substantiated with the studies conducted by Naugraiya and Singh (2004) and Duhoon *et al*. (2004) in sesame. This increase in yield may be attributed to the increasing levels of sulphur which resulted in greater accumulation of carbohydrates, protein and their translocation to the reproductive structures, which in turn improved all the growth and yield determining characters, resulting more seed yield. As seed yield is primarily a function of cumulative effect of yield contributing characters, the higher values of these yield attributes can be assigned as the most probable reason for significantly higher seed yield. It is well evidenced from the positive correlation between crop dry matter and nutrient uptake by the crop (Table 3). Further, correlation analysis also substantiated strong dependence of yield attributes *viz.* capsules/plant (0.968), seeds/capsule (0.978) and test weight (0.923) on seed yield. Stalk yield also recorded higher with increasing rates of sulphur application. It might be directly associated with the improved biomass per plant under higher level of sulphur fertilization at successive growth stages and increase in various morphological parameters like plant height, number of branches/plant possibly as a result of higher uptake of nutrients.

**Sulphur use efficiency:** Agronomic efficiency and apparent recovery of S were significantly higher in all the integrated nitrogen management treatments over control treatment (Table 2). Application of 50% RDN + 50% N through vermicompost showed significantly highest agronomic efficiency (3.11 kg seed/kg S) and apparent recovery of S (3.44%) over rest of the treatments and was accompanied by 50% RDN + 50% N through FYM, 100% RDN, 50% N through FYM + 50% N through vermicompost. The physiological efficiency remained indifferent to different integrated nitrogen management treatments during both the years as well as in pooled analysis. The maximum agronomic efficiency (4.93 kg seed/kg S), apparent recovery (5.04%) and physiological efficiency of sulphur (98.22 kg/kg S uptake) were obtained when level of sulphur was raised from control to 20 kg/ha. Further, increase in level of sulphur showed progressive decline in all the efficiencies. Based on production function, mean level of 49.04 kg/ha in sesame was found to be the optimum level of sulphur corresponding with seed yield of 738.85 kg/ha and a mean response of 2.96 kg/ha (Table 4 & Fig. 3).

Based on the results of two years experimentation, it may be inferred that application of 50% RDN + 50% N through vermicompost was the most effective integrated nitrogen management practice in sesame which provided the maximum seed yield (799 kg/ha) and net returns (₹ 52872/ha) with a B: C ratio of 2.96. Application of 50% RDN + 50% N through FYM produced the seed yield of 756 kg/ha and fetched net returns of ₹ 51281/ha with the maximum B: C ratio (3.11). Thus, it was found equally effective and the next better integrated nitrogen management option under scarce conditions. Bringing about significantly higher seed yield (728 kg/ha), net returns (₹ 46624/ha) with the highest B: C ratio of 2.80, application of 40 kg S/ha was found as the most remunerative level of sulphur fertilization in sesame. Based on production function, application of sulphur at 49.04 kg/ha was worked out to be the optimum dose for sesame.

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Fig.1 Effect of integrated nitrogen management and sulphur fertilization on seed yield of sesame in 2020 &2021

Fig. 2 Effect of integrated nitrogen management and sulphur fertilization on stalk yield of sesame in 2020 &2021

Fig. 3 Seed yield of sesame (Y) as a function of sulphur fertilization (Pooled)

**Table 1 Effect of integrated nitrogen management and sulphur fertilization on net returns and B: C ratio in sesame**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Net returns (2000px-Indian_Rupee_symbol/ha)** | **B: C ratio** |
| **2020** | **2021** | **Pooled** | **2020** | **2021** | **Pooled** |
| **Integrated nitrogen management** |
| **N0**- Control  | 27653 | 22595 | 25124 | 2.29 | 2.00 | 2.15 |
| **N1**- 100% RDN | 53609 | 47940 | 50774 | 3.38 | 3.02 | 3.20 |
| **N2**- 100% RDN through FYM  | 41499 | 35880 | 38689 | 2.63 | 2.35 | 2.49 |
| **N3**- 100% RDN through vermicompost  | 39246 | 33870 | 36558 | 2.28 | 2.06 | 2.17 |
| **N4**- 50% RDN + 50% N through FYM  | 54361 | 48202 | 51281 | 3.28 | 2.93 | 3.11 |
| **N5**- 50% RDN + 50% N through vermicompost  | 56106 | 49639 | 52872 | 3.12 | 2.80 | 2.96 |
| **N6**- 50% N through FYM + 50% N through vermicompost  | 45603 | 40051 | 42827 | 2.62 | 2.37 | 2.50 |
| SEm+ | 1131 | 856 | 709 | 0.08 | 0.07 | 0.05 |
| CD (P=0.05) | 3232 | 2446 | 2070 | 0.22 | 0.20 | 0.15 |
| CV (%) | 8.62 | 7.46 |  - | 9.63 | 9.45 |  - |
| **Sulphur levels**  |   |   |   |   |   |   |
| **S0**- Control  | 36199 | 31049 | 33624 | 2.47 | 2.20 | 2.33 |
| **S20**- 20 kg/ha | 46019 | 40369 | 43194 | 2.84 | 2.54 | 2.69 |
| **S40**- 40 kg/ha | 49599 | 43649 | 46624 | 2.96 | 2.65 | 2.80 |
| **S60**- 60 kg/ha | 49939 | 43889 | 46914 | 2.94 | 2.63 | 2.78 |
| SEm+ | 754 | 560 | 550 | 0.05 | 0.05 | 0.04 |
| CD (P=0.05) | 2152 | 1599 | 1547 | 0.13 | 0.14 | 0.11 |
| CV (%) | 7.60 | 6.46 | - | 7.57 | 8.70 | - |

**Table 2 Effect of integrated nitrogen management and sulphur fertilization on sulphur use efficiency of sesame**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment**  | **AEs (kg seed/kg S)** | **REs (%)** | **PEs (kg/kg S)** |
| **2020** | **2021** | **Pooled** | **2020** | **2021** | **Pooled** | **2020** | **2021** | **Pooled** |
| **Integrated nitrogen management** |
| **N0**- Control  | 1.90 | 1.77 | 1.83 | 2.01 | 1.79 | 1.90 | 70.16 | 72.70 | 71.43 |
| **N1**- 100% RDN | 2.95 | 2.81 | 2.88 | 3.31 | 3.04 | 3.17 | 66.05 | 68.03 | 67.04 |
| **N2**- 100% RDN through FYM  | 2.59 | 2.45 | 2.52 | 2.81 | 2.53 | 2.67 | 68.38 | 71.38 | 69.88 |
| **N3**- 100% RDN through vermicompost  | 2.71 | 2.58 | 2.64 | 2.98 | 2.69 | 2.84 | 67.30 | 70.50 | 68.90 |
| **N4**- 50% RDN + 50% N through FYM  | 3.03 | 2.87 | 2.95 | 3.47 | 3.19 | 3.33 | 64.31 | 66.17 | 65.39 |
| **N5**- 50% RDN + 50% N through vermicompost  | 3.20 | 3.03 | 3.11 | 3.58 | 3.30 | 3.44 | 66.18 | 67.61 | 66.89 |
| **N6**- 50% N through FYM + 50% N through vermicompost  | 2.86 | 2.71 | 2.78 | 3.22 | 2.97 | 3.09 | 65.68 | 67.48 | 66.58 |
| SEm+ | 0.12 | 0.14 | 0.08 | 0.14 | 0.16 | 0.09 | 2.76 | 2.85 | 1.72 |
| CD (P=0.05) | 0.30 | 0.33 | 0.23 | 0.36 | 0.40 | 0.27 | NS | NS | NS |
| CV (%) | 9.89 | 11.70 | - | 10.59 | 13.03 | - | 9.27 | 9.28 | - |
| **Sulphur levels**  |  |  |  |  |  |  |  |  |  |
| **S0**- Control  | - | - | - | - | - | - | - | - | - |
| **S20**- 20 kg/ha | 5.05 | 4.80 | 4.93 | 5.32 | 4.77 | 5.04 | 95.30 | 101.14 | 98.22 |
| **S40**- 40 kg/ha | 3..50 | 3.30 | 3.40 | 3.92 | 3.62 | 3.77 | 89.58 | 91.53 | 90.55 |
| **S60**- 60 kg/ha | 2.45 | 2.30 | 2.38 | 2.97 | 2.76 | 2.86 | 82.75 | 83.82 | 83.29 |
| SEm+ | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 1.35 | 1.54 | 1.33 |
| CD (P=0.05) | 0.17 | 0.19 | 0.16 | 0.18 | 0.17 | 0.18 | 3.90 | 4.47 | 3.74 |
| CV (%) | 7.12 | 8.46 | - | 6.87 | 7.04 | - | 6.92 | 7.67 | - |

Where, AEs = Agronomic efficiency REs = Apparent recovery efficiency PEs = Physiological efficiency

**Table 3 Correlation coefficients and linear regression equations showing relationship between seed yield (Y) of sesame (kg/ha) and independent variables (X)**

|  |  |  |  |
| --- | --- | --- | --- |
| **S. No.** | **Independent variables (x)** | **Correlation coefficient (r)** | **Regression equation (Y= a + byx.X)** |
| **2020** | **2021** | **Pooled** | **2020** | **2021** | **Pooled** |
| 1. | Dry matter at harvest | 0.910\*\* | 0.997\*\* | 0.904\*\* | Y = -79.902 + 1.981X1 | Y = -67.981 + 1.874X1 | Y = -74.215 + 1.931X1 |
| 2. | Branches/plant  | 0.940\*\* | 0.905\*\* | 0.924\*\* | Y = -292.861 + 307.555X2 | Y = -190.481 + 277.266X2 | Y = -239.378 + 292.194X2 |
| 3. | No. of capsules/plant  | 0.979\*\* | 0.952\*\* | 0.968\*\* | Y = -160.445 + 26.621X3 | Y = -72.498 + 25.195X3 | Y = -117.525+ 25.981X3 |
| 4. | Number of seeds/capsule  | 0.982\*\* | 0.973\*\* | 0.978\*\* | Y = -258.013 + 21.473X4 | Y = -317.695 + 22.233X4 | Y = -288.291 + 21.859``X4 |
| 5. | Test weight (g) | 0.930\*\* | 0.916\*\* | 0.923\*\* | Y = -150.432 + 336.749X5 | Y = -160.025 + 333.026X5 | Y = -159.171 + 336.438X4 |
| 6. | Total N uptake | 0.968\*\* | 0.970\*\* | 0.969\*\* | Y = 259.643 + 9.286X7 | Y = 240.194 + 9.384X7 | Y = 249.726 + 9.337X5 |
| 7. | Total P uptake | 0.977\*\* | 0.966\*\* | 0.972\*\* | Y = 209.103 + 54.191X8 | Y = 229.714 + 51.758X8 | Y = 219.447 + 53.024X7 |
| 8. | Total K uptake | 0.974\*\* | 0.979\*\* | 0.977\*\* | Y = 199.384 + 26.061 X9 | Y = 181.104 + 26.866 X9 | Y = 189.708 + 26.475X8 |
| 9. | Total S uptake  | 0.969\*\* | 0.968\*\* | 0.969\*\* | Y = 204.408 + 113.055 X9 | Y = 197.461 + 114.105 X9 | Y = 301.056 + 113.543 X9 |

\*\* Significant at 1 per cent level of significance

**Table 4 Seed yield (Y) as a function of sulphur (S) fertilization**

 **(Y = b0 + b1S + b2 S2)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Study parameters** | **2020** | **2021** | **Pooled** |  |
| 1. Partial regression coefficients  |  |  |  |  |
| b0 | 613.5 | 573.5 | 593.6 |  |
| b1 | 5.925 | 5.625 | 5.787 |  |
| b2 | -0.0587 | -0.0562 | -0.0575 |  |
| 2. Coefficient of  |  |  |  |  |
|  (i) Determination (R2) | 0.996\*\* | 0.996\*\* | 0.996\*\* |  |
|  (ii) Multiple correlation (R) | 0.998\*\* | 0.998\*\* | 0.998\*\* |  |
| 3. Maximum levels of S (Kg/ha) | 50.43 | 50.00 | 50.26 |  |
| 4. Yield at S maximum | 762.89 | 714.13 | 738.77 |  |
| 5. Optimum levels of S (Kg/ha) | 49.23 | 44.75 | 49.04 |  |
| 6. Yield at optimum level of S (Kg/ha) | 762.80 | 714.04 | 738.85 |  |
| 7. Response of optimum level of S (Kg/ha) | 149.39 | 140.63 | 145.17 |  |
| 8. Response per kg S at optimum level | 3.03 | 3.14 | 2.96 |  |
| 9. Response per kg S at S40 level | 3.58 | 3.38 | 3.49 |  |

 **Note**:- i. The yield, S levels, responses and intercepts are given in kg/ha

 ii. Total partial regression coefficient (b1 and b2) are based on X units of 20 kg

 iii. \*\* Significant at 1% level of significance