Effect of Integrated Nitrogen Management and Sulphur Fertilization on Seed yield, Nutrient concentration and uptake and soil parameters of Sesame (*Sesamum indicum* L.) 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 nutrient management practices (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 revealed that different integrated nitrogen management practices had a significant effect on seed yield, nutrient concentration and uptake of sesame. Application of 50% RDN + 50% N through vermicompost (N_5) and 50% RDN + 50% N through FYM (N_4), were the most superior and equally effective in enhancing these parameters among all the treatments. The maximum seed yield (799 kg/ha)was obtained under 50% RDN + 50% N through vermicompost treatment. Producing the seed and stalk yields of 756and 2329 kg/ha, application of 50% RDN + 50% N through FYM was found equally effective. Results further showed that 50% RDN + 50% N through vermicompost and 50% RDN + 50% N through FYM were significantly better and statistically similar in enhancing N, P, K and S concentration and their uptake and protein and oil content in seed. Further, it was revealed that progressive increase in sulphur fertilization significantly improved the yield and nutrient uptake in sesame. Addition of 40kg sulphur resulted in increment of about 24.1 and 33.0 percent in seed and stalk yield, respectively over control viz-a-viz enhancing nutrient uptake by sesame. However, treatment receiving 60 kg S/ha showed higher but statistically similar results as that of treatment receiving 40 kg S/ha. Maximum values of N, P and S contents in soil after harvest were recorded at 60 kg S/ha with 40 kg S/ha being statistical at par

Keywords: Sesame, Yield, Nutrient, Sulphur, Soil 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). Its seed is used in a variety of food goods, both raw and roasted, as well as industrial applications such as soaps, lubricants, lamp oil, and as a cosmetic, medicinal and animal feed ingredient. It has lots of oil, proteins, carbohydrates, and important minerals, as well as a lot of methionine and tryptophan, fibres, and secondary metabolites including lignin, saponins, flavonoids, and phenolic compounds(Verma & Saxena, 2022). Sesame meal-based products have also been proven to be beneficial for diabetics due to their low carbohydrate content and high protein content (Bigoniya*et al.*, 2012). Sesame seeds are known as "the seeds of immortality" because of their high antioxidant content(Yadav et al., 2023).

Globally, sesame is farmed 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.Sesame productivity in Rajasthan remains significantly lower compared to national and global levels due to low and irregular rainfall, cultivation on marginal and sub-marginal soils with poor fertility, ineffective agronomic practices, and insufficient or nonexistent fertilizer use(Kumar & Sharma, 2021). Proper fertilization is essential to unlock the crop's yield potential. While inorganic fertilizers have proven effective in boosting productivity, their rising costs pose a growing challenge (Shaikh et al., 2011).

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).Given the critical role of nitrogen and sulphur in enhancing the growth, yield, and oil quality of sesame, their integrated management is essential, particularly in regions like Rajasthan where soils are low in fertility and deficient in sulphur. Addressing the challenges of low productivity due to inadequate fertilization and poor agronomic practices, this study aims to evaluate the combined effect of organic and inorganic nitrogen sources along with sulphur application to optimize sesame production.

MATERIALS AND METHOD

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 26^0 05' North latitude, 75^0 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 45^oC, whereas, the minimum temperature in winter falls as low as 1-2^0 C.During the experimentation period, the minimum and maximum temperatures ranged from 10.5 to 25.4^0 C and 30.2 to 37.6^0 C during *Kharif* 2020 and 13.0 to 25.7^0 C and 30.1 to 38.2^0 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 (N_0), 100% RDN (N_1), 100% RDN through FYM (N_2), 100% RDN through vermicompost (N_3), 50% RDN + 50% N through FYM (N_4), 50% RDN + 50% N through vermicompost (N_5) and 50% N through FYM + 50% N through vermicompost (N_6) 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 seed and stalk samples from each plot were analyzed to determine nitrogen, phosphorus, potassium and sulphur content. Nutrient uptake was calculated by multiplying the percent of nutrient content of seed/stalk with their respective yield and then total uptake was calculated. Initial and final soil samples after two years of experimentation were collected from 0-15 cm surface soil. The soil organic carbon concentration was estimated through the method of walkley and black. Soil was air dried and analysis of chemical properties of N, P, K and S was done using standard procedures. All the observations 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 critical difference at 5 % level of probability.

RESULTS AND DISCUSSION

Seed, stalk and biological yield: All the integrated nitrogen management treatments produced significantly higher seed, stalk and biological yields of sesame in pooled analysis in comparison to control (Table 1). The application of 50% RDN + 50% N from vermicompost (N4) resulted in the significantly higher seed, stalk, and biological yields of 799, 2441, and 3240 kg/ha, respectively, surpassing all other treatments. However, treatment receiving 50% RDN + 50% N from FYM (N-) also demonstrated significant increase in of 56.7%, 43.7%, and 46.7% for seed, stalk, and biological yields, respectively, compared to the control and was startistically similar and equally effective as that of treatment receiving 50% RDN + 50% N from vermicompost. Higher seed and stalk yield under application of organic source of nitrogen were probably a consequence of greater amount of nutrient uptake by seed and stalk. Application of FYM, inorganic fertilizer and vermicompost increased the supply of easily assimilated major as well as micronutrients to plant, besides mobilizing unavailable nutrients into available form. It is needed mostly by young, fast growing tissues and performs a number of functions related to growth, development, photosynthesis and utilization of carbohydrates. These all processes favorably improved with application of organic manure. The results are substantiated with the studies conducted by Naugraiya and Singh (2004) and Duhoon*et al.* (2004) in sesame. Sulphur fertilization at 40 kg/ha recorded significantly higher seed, stalk and biological yield (728, 2246 and 2974 kg/ha) of sesame than 20 kg/ha and control. However, it was found at par with 60 kg S/ha, wherein, 24.1, 33.0 and 30.8 per cent higher seed, stalk and biological yield than control were recorded, respectively. 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. Significant improvement in yield attributes and yield due to sulphur fertilization have also been reported earlier by Sarkar and Saha (2005) and Tripathi *et al.* (2007) in sesame crop.

Nutrient concentration and uptake and quality: N, P, K and S concentration in seed and stalk due to integrated nitrogen management over control (Table 2 & 3). Application of 50% RDN + 50% N through vermicompost, 50% RDN + 50% N through FYM and 100% RDN were the most superior and equally effective treatments in this regard. Being at par among themselves, these treatments also registered significantly higher protein content of 14.4, 14.0 and 12.6 per cent in comparison to control. Integrated nitrogen management treatments also registered significant increase in uptake of N, P, K and S by crop at harvest stage as compared to control. The maximum uptake of 57.08, 10.54, 22.10 and 5.04 kg N, P, K and S/ha was noted under 50% RDN + 50% N through vermicompost. Application of 50% RDN + 50% N through FYM and 100% RDN were the next better and statistically similar treatments that also witnessed 88.2 and 79.4 per cent higher uptake of N; 83.7 and 74.8 per cent of P; 79.0 and 71.6 per cent of K and 76.2 and 67.9 per cent of S in comparison to control, respectively.Remaining at par among themselves, 50% RDN + 50% N through vermicompost and 50% RDN + 50% N through FYM registered 11.4 and 9.1 per cent higher oil content over control. These treatments also improved the oil yield by magnitude of 185.03 and 156.31 kg/ha, respectively. Higher concentration of in crop dry matter can be attributed to the greater availability of nutrients in soil under superior treatments of inorganic and organic manure combinations. The findings of the present investigation are in close agreement with those of Vaiyapuri*et al.* (2003), Yadav *et al.* (2022),Kumar *et al.* (2023),Vijayakumari*et al.* (2012), Abdullahi *et al.* (2013) in sesame. N, P, K and S concentration in seed and stalk of sesame attained the maximum values at 60 kg S/ha. However, this level of sulphur fertilization showed statistical similarity with 40 kg S/ha. Progressive increase in sulphur level brought about significantly higher uptake of N, P, K and S up to 40 kg/ha over preceding levels. It was found at par with 60 kg/ha wherein, the maximum uptake of 54.68 kg N; 10.19 kg P; 21.51 kg K and 4.93 kg S/ha were recorded. Protein content in sesame seed increased significantly with successive increase in level of sulphur up to 40 kg/ha over lower levels (Table 1). Application of sulphur at 40 and 60 kg/ha significantly increased the oil content in sesame seed by 10.4 and 11.1 per cent and oil yield by 35.8 and 37.9 per cent over control. However, they showed statistical resemblance with each other. The positive influence of sulphur application on nutrient concentration in crop appears to be due to improved nutrimental environment in rhizosphere as well as in plant system. The adequate supply of sulphur in early crop season resulted in greater availability of nutrients including K and S and of N in particular in the root zone depth of the soil.Increased availability of these nutrients coupled with accelerated metabolic activities at the cellular level probably might have increased the nutrient uptake and their accumulation in various plant parts. The increased accumulation of nutrients especially N and S in plant parts possibly with greater metabolism led to greater translocation of these nutrients to reproductive parts of the crop which appears to be the most probable reason of higher nutrient concentration inseed and stalk due to sulphur fertilization. These results are in close conformity with the findings of Yadav *et al.* (2008)and Yadav *et al.* (2020) in sesame.

Soil parameters: Different integrated nitrogen management practices had a significant effect in respect to available N, P, K and S of soil during both the years of cultivation (Table 4). There was a reduction in available N, P and K content in soil after two years of experimentation owing to the absorption of these nutrients for the crop growth and other losses. Decrease in N, P and K was less under 100% RDN through FYM compared to that other practice. The highest mean concentration of N, P and K in soil after harvest was observed under application of 100 % RDN through FYM treatment that was closely accompanied by 50% N through FYM + 50% N through vermicompost and 100% RDN through vermicompost.There was no significant difference in soil OC and S in soils under different integrated nitrogen management in both the years. The maximum values of N, P and S contents in soil after harvest were recorded at 60 kg S/ha. However, it showed statistical similarity with 40 kg S/ha. Addition of organic matter in to the soil through organic manures helped in modifying the soil reaction favorably to enhance the availability of organic carbon content and resulted in improvement of the soil fertility. Similar observations had also been reported by Jat and Ahlawat (2006) and *Nayek et al.* (2014) in sesame.

Conclusion

The study is based on two-year study it can be concluded that application of 50% RDN + 50% N through vermicompost as integrated nitrogen management and 40 kg S/ha assulphur fertilization is better for realizing higher yield, nutrient concentration and uptake, oil content and oil yield and soil fertility in sesame production under semi-arid condition of Rajasthan.

REFERENCES

Abdullahi, R.,Sheriff, H. H. and Lihan 2013. Combine effect of bio-fertilizer and poultry manure on growth and nutrient uptake and microbial population associated with sesame (*Sesamum indicum* L.) in Nigeria*. IOSR Journal of Environmental Science, Toxicology and Food Technology***5**: 60-65. Anonymous 2020-21. Government of Rajasthan, Department of Agriculture. https://agriculture.rajasthan.gov.in. Final estimate 2020-21 pdf.

Bigoniya, P., Nishad, R. and Singh, C.S. 2012. Preventive effect of sesame seed cake on hyperglycemia and obesity against high fructose- diet induced Type-2 diabetes in rats. *Food chemistry***133**: 1355-1361.

DAC&FW 2021. Department of Agriculture, Cooperation & Farmers Welfare. Third Advance Estimates of Production of Commercial Crops for 2020-2021.http://agricoop.gov.in/sites/default/files/Time-series-3rd-Adv-Estimate-2020-21-Final-Press.Pdf.

Duhoon, S.S., Jyotishi, A., Deshmukh, M.R. And Singh, N.B. 2004. Optimization of sesame production through bio natural inputs. In Proceedings of the 4th *International Crop Science Congress* September. htttps:// www.cropscience.org.au/icsc.2004.

FAOSTAT 2019. Food and Agriculture organization Statistical Database. Available Online, 2019. http://faostat.fao.org/.

Gomez, A.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research (2^{nd} ed.). *John Wiley* and Sons. Singapore.

Jat, R. S. and Ahlawat, I. P. S. 2006. Direct and residual effect of VC, bio fertilizers and phosphorus on soil nutrient dynamics and productivity of chickpea-fodder maize sequence. *Journal of Sustainable Agriculture* **28**(1): 51-54.

Kumar, A., Saini, K. S., Dasila, H., Kumar, R., Devi, K., Bisht, Y. S., Yadav, M., Kothiyal, S., Chilwal, A., Maithani, D., and Kaushik, P. (2023). Sustainable intensification of cropping systems under conservation agriculture practices: Impact on yield, productivity and profitability of wheat. *Sustainability*, 15(9), 7468.https://doi.org/10.3390/su15097468.

Naugraiya, M.N and Singh, J.P. 2004. Role of nitrogen and sulphur on performance of *Sesamum indicum* under plantation of *Dalbergia sissoo* in marginal land of Chhattisgarh. *Indian Journal of Agroforestry***6**(1):89-91.

Nayek, S. S., Brahmchari, K. and Chowdhury, R.Md. 2014. Integrated approach in nutrient management of sesame with special reference to its yield, quality and nutrient uptake. *The Bioscan***9**(1): 101-105.

Prasad, R. 2017. Texbook of Field Crop Production Commercial Crops Vollume II. Indian Council of Agricultural Research, New Delhi 2: 200.

Sarker, R.K. and Saha, A. 2005. Analysis of growth and productivity of sesame (*Sesamum indicum* L.) in relation to sulphur and boron. *Indian Journal of Plant Physiology* **10**(4): 333-337.

Shaikh, A.A., Hankare, R.H. and Kamble, R.S. 2011. Effect of integrated nutrient management on uptake pattern of summer sesamum (*Sesamumindicum* L.). *Journal of Agricultural Research Technology***36**(3): 374-378. Tandon, H.L.S. 1995. Sulphur research and agricultural production in India. Fertilizer Development and Consultation Organization, New Delhi Pp.125.

Tripathi, M.L., Rajput, R.L. and Chaursia, S.K. 2007. Effect of sources and levels of sulphur on yield attributes, yield and economics of sesame. *Advances in PlantSciences***20**(2): 501-502.

Vaiyapuri, V., Amudha, A., Sriramachandrasekharan, M.V. and Ravichandran, M. 2003. Effect of sulphur levels and organics on seed quality and nutrient uptake of sesame. *Research on Crops***4**(3): 327-330.

Vijaya Kumari, B. and Hiranmai, Y. R. 2012. Influence of fresh, composted and vermicomposted parthenium and poultry manure on the growth characters of sesame (*Sesamum indicum* L.). *Journal of Organic Systems***7**(1): 14-19.

Yadav, M., Vashisht, B.B., Jalota, S.K., Kumar, A., Kumar, D., 2022. Sustainable water management practices for intensified agriculture. In soil-water, agriculture, and climate change: exploring linkages. *Springer* Int. Pub, Cham, pp. 131–161.

Yadav, P., Yadav, S.S., Garg, K. and Yadav, S. 2020. Effect of sulphur and zinc fertilization on growth, yield attributes and grain yield of sesame (Sesamum indicum L.). *Indian Journal of Agronomy***65** (1): 120-124.

Yadav, S.B., Adibi, Singh, R.P. and Singh, A. 2008. Response of sulphur nutrition on nutritional characteristics of oil and cake of sesame (*Sesamum indicum* L.) Varieties. *Journal of Oilseeds Research* **25**(1): 38-40.

Verma, P., & Saxena, A. (2022). Integrated nutrient management in sesame (*Sesamum indicum* L.) with organic amendments and Azospirillum inoculation. Agriculture and Natural Resources, 56(4), 1–10. https://doi.org/10.1016/j.anr.2022.04.001

Yadav, K., Sharma, R., & Singh, S. (2023). Effect of sulphur application on seed yield and quality of sesame (Sesamum indicum L.) under varying fertility regimes. Journal of Soil Science and Crop Protection, 23(2), 135-146. https://www.researchgate.net/publication/385574270

Kumar, S., & Sharma, M. (2021). Impact of integrated nutrient management on growth and yield attributes of sesame (Sesamum indicum L.) under semi-arid conditions. International Journal of Chemical Studies, 9(4), 1687-1692. https://www.researchgate.net/publication/320806064

Table1Effect of integrated nitrogen management and sulphur fertilization on seed, stalk and biological yields (2 years pooled data) and protein , oil content and oil yield of sesame

Treatments	Yield (Kg/ha)											
	Seed	Stalk	Biological	Protein content (%)			Oil content (%)			Oil yield (kg/ha)		
	Pooled	Pooled	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Integrated nitrogen management												
N_0- Control	471	1567	2038	17.27	16.55	16.91	44.13	43.75	43.94	217.09	198.05	207.57
N_1- 100% RDN	738	2252	2990	19.43	18.65	19.04	47.25	46.90	47.07	360.76	336.82	348.79
N_2- 100% RDN through FYM	646	1969	2615	18.74	17.97	18.35	47.05	46.67	46.86	315.67	292.19	303.93

N_3- 100% RDN through vermicompost	678	2066	2745	18.97	18.12	18.54	47.52	47.12	47.32	333.46	310.69	322.08
N_4- 50% RDN + 50% N through FYM	756	2329	3085	19.66	18.87	19.27	48.09	47.78	47.94	377.09	350.67	363.88
N_5- 50% RDN + 50% N through vermicompost	799	2441	3240	19.74	18.95	19.34	49.14	48.79	48.97	407.07	378.13	392.60
N_6- 50% N through FYM + 50% N through vermicompost	714	2150	2864	19.20	18.42	18.81	47.15	46.78	46.96	348.35	324.96	336.66
SEm±	13	43	55	0.38	0.33	0.25	0.99	1.02	0.71	11.58	11.10	8.02
CD (P=0.05)	38	125	162	1.09	0.94	0.73	2.83	2.90	2.07	33.08	31.70	23.39
CV (%)	-	-	-	6.96	6.24	-	7.26	7.52	-	11.90	12.28	-
Sulphur levels												
S_0- Control	592	1749	2341	16.06	15.31	15.69	44.25	43.90	44.08	271.93	252.19	262.06
S_{20}- 20 kg/ha	691	2122	2812	18.63	18.19	18.41	46.72	46.44	46.58	334.49	311.56	323.02
S_{40}- 40 kg/ha	728	2246	2974	20.44	19.44	19.94	48.68	48.42	48.55	367.58	342.35	354.97
S_{60}- 60 kg/ha	735	2326	3061	20.88	19.94	20.41	49.11	48.55	48.83	374.28	346.19	360.24
SEm±	10	33	42	0.25	0.21	0.19	0.63	0.58	0.52	5.70	6.40	5.37
CD (P=0.05)	28	93	118	0.70	0.59	0.53	1.80	1.66	1.45	16.27	18.26	15.10
CV (%)	-	-	-	5.92	5.17	-	6.13	5.68	-	7.75	9.37	-

Table 2 Effect of integrated nitrogen management and sulphur fertilization on N and P concentration in sesame seed and stalk and total N and P uptake

Treatments	N concentration (%)						Total N uptake (kg/ha)			P concentration (%)						Total P uptake (kg/ha)		
	Seed			Stalk						Seed			Stalk					
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
Integrated nitrogen management																		
N_0	2.76	2.65	2.71	1.015	0.980	0.997	29.85	27.35	28.60	0.622	0.544	0.583	0.177	0.171	0.174	5.88	5.14	5.51
N_1	3.11	2.98	3.05	1.273	1.250	1.262	52.98	49.66	51.32	0.709	0.654	0.681	0.203	0.199	0.201	10.06	9.19	9.63
N_2	3.00	2.88	2.94	1.204	1.160	1.182	44.40	40.81	42.60	0.686	0.635	0.660	0.194	0.190	0.192	8.50	7.71	8.11
N_3	3.03	2.90	2.97	1.224	1.190	1.207	47.19	43.68	45.44	0.692	0.640	0.666	0.197	0.192	0.194	9.01	8.18	8.60
N_4	3.15	3.02	3.08	1.293	1.290	1.292	55.39	52.28	53.83	0.716	0.663	0.689	0.210	0.205	0.207	10.59	9.65	10.12
N_5	3.16	3.03	3.09	1.313	1.300	1.307	58.78	55.38	57.08	0.713	0.660	0.686	0.207	0.201	0.204	11.03	10.05	10.54
N_6	3.07	2.95	3.01	1.253	1.210	1.232	50.16	46.60	48.38	0.700	0.645	0.672	0.198	0.197	0.197	9.50	8.73	9.11
SEm±	0.06	0.05	0.04	0.025	0.031	0.020	1.48	1.29	0.98	0.014	0.014	0.010	0.004	0.003	0.002	0.36	0.29	0.23
CD (P=0.05)	0.18	0.15	0.12	0.073	0.089	0.059	4.21	3.68	2.86	0.039	0.040	0.028	0.010	0.010	0.007	1.02	0.83	0.67
CV (%)	7.35	6.44	-	7.20	9.05	-	10.56	9.90	-	6.78	7.60	-	6.25	6.03	-	13.43	11.98	-
Sulphur levels																		
S_0	2.57	2.45	2.51	1.090	1.060	1.075	35.09	32.79	33.94	0.621	0.524	0.573	0.181	0.177	0.179	7.01	6.13	6.57
S_{20}	2.98	2.91	2.95	1.210	1.180	1.195	47.55	44.59	46.07	0.683	0.614	0.649	0.196	0.192	0.194	9.13	8.19	8.66
S_{40}	3.27	3.11	3.19	1.290	1.260	1.275	54.29	50.32	52.31	0.722	0.692	0.707	0.206	0.201	0.204	10.17	9.41	9.79
S_{60}-	3.34	3.19	3.27	1.310	1.290	1.300	56.64	52.73	54.68	0.738	0.708	0.723	0.209	0.204	0.207	10.59	9.79	10.19
SEm±	0.04	0.04	0.03	0.018	0.020	0.016	1.10	0.97	0.83	0.010	0.010	0.008	0.002	0.002	0.002	0.18	0.16	0.15
CD (P=0.05)	0.11	0.10	0.09	0.051	0.057	0.044	3.14	2.77	2.34	0.028	0.030	0.023	0.007	0.006	0.005	0.53	0.46	0.43
CV (%)	5.76	5.67	-	6.75	7.58	-	10.40	9.85	-	6.42	7.51	-	5.57	5.30	-	9.15	8.82	-

Symbols description in materials and methods

Table 3 Effect of integrated nitrogen management and sulphur fertilization on K and S concentration in sesame seed and stalk and total K and S uptake

Treatments	K concentration (%)						Total K uptake (kg/ha)			S concentration (%)						Total S uptake (kg/ha)		
	Seed			Stalk						Seed			Stalk					
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Integrated nitrogen management																		
N_0	0.928	0.825	0.877	0.506	0.486	0.496	12.63	11.31	11.97	0.166	0.147	0.157	0.132	0.125	0.129	2.92	2.62	2.77
N_1	1.062	0.990	1.026	0.577	0.564	0.571	21.29	19.78	20.54	0.187	0.172	0.180	0.149	0.143	0.146	4.83	4.46	4.65
N_2	1.030	0.925	0.978	0.552	0.534	0.543	17.99	16.23	17.11	0.181	0.162	0.172	0.144	0.137	0.141	4.10	3.70	3.90
N_3	1.044	0.944	0.994	0.559	0.541	0.550	19.09	17.33	18.21	0.183	0.165	0.174	0.146	0.139	0.143	4.36	3.95	4.15
N_4	1.067	1.006	1.037	0.585	0.572	0.579	22.20	20.67	21.43	0.188	0.174	0.181	0.152	0.146	0.149	5.07	4.68	4.88
N_5	1.071	1.010	1.040	0.569	0.551	0.560	22.94	21.27	22.10	0.191	0.177	0.184	0.148	0.142	0.145	5.24	4.84	5.04
N_6	1.057	0.964	1.010	0.593	0.578	0.586	20.74	19.10	19.92	0.184	0.170	0.177	0.153	0.147	0.150	4.70	4.34	4.52
SEm±	0.026	0.022	0.017	0.010	0.011	0.008	0.62	0.59	0.43	0.003	0.003	0.002	0.003	0.003	0.002	0.18	0.12	0.11
CD (P=0.05)	0.074	0.064	0.050	0.029	0.032	0.022	1.77	1.69	1.25	0.009	0.009	0.007	0.008	0.009	0.006	0.50	0.35	0.31
CV (%)	8.71	8.17	-	6.19	7.20	-	10.95	11.40	-	5.96	6.85	-	6.64	8.11	-	13.70	10.45	-
Sulphur levels																		
S_0	0.932	0.847	0.890	0.521	0.514	0.518	14.91	13.91	14.41	0.168	0.152	0.160	0.132	0.125	0.129	3.36	3.07	3.21
S_{20}	1.019	0.927	0.973	0.556	0.542	0.549	19.29	17.69	18.49	0.181	0.165	0.173	0.145	0.138	0.142	4.42	4.02	4.22
S_{40}	1.087	0.999	1.043	0.584	0.562	0.573	21.55	19.66	20.60	0.190	0.174	0.182	0.153	0.147	0.150	4.93	4.52	4.72
S_{60}-	1.110	1.035	1.073	0.591	0.569	0.580	22.47	20.56	21.51	0.193	0.176	0.185	0.155	0.150	0.153	5.14	4.72	4.93
SEm±	0.015	0.012	0.012	0.007	0.007	0.006	0.39	0.39	0.33	0.002	0.002	0.002	0.002	0.002	0.002	0.10	0.08	0.08
CD (P=0.05)	0.044	0.036	0.034	0.020	0.019	0.016	1.11	1.13	0.92	0.006	0.006	0.005	0.006	0.005	0.004	0.27	0.24	0.22
CV (%)	6.75	5.99	-	5.59	5.66	-	9.08	10.08	-	5.02	5.70	-	6.39	5.39	-	9.89	9.41	-

Symbols description in materials and methods

Table 4 Effect of integrated nitrogen management and sulphur fertilization on organic carbon, available N and P in soil after harvest of sesame

Treatments	**Organic carbon (%)**			**Available N (kg/ha)**			**Available P_2O_5 (kg/ha)**			**Available K_2O (kg/ha)**			**Available S (mg/kg)**		
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
Integrated nitrogen management															
N_0	0.227	0.235	0.231	104.81	103.51	104.16	10.78	9.55	10.16	128.48	125.76	127.12	9.39	9.55	9.47
N_1	0.239	0.242	0.241	115.17	113.57	114.37	11.70	10.51	11.10	140.96	138.70	139.83	9.47	9.64	9.56
N_2	0.257	0.264	0.260	125.17	123.52	124.35	12.62	11.35	11.99	148.30	146.18	147.24	10.24	10.41	10.32
N_3	0.253	0.255	0.254	120.83	118.14	119.48	12.19	10.92	11.55	145.14	143.02	144.08	9.86	10.07	9.97
N_4	0.250	0.251	0.250	118.20	116.72	117.46	11.95	10.73	11.34	144.08	142.37	143.23	9.73	9.84	9.78
N_5	0.243	0.246	0.244	115.65	114.07	114.86	11.76	10.53	11.14	141.65	139.86	140.76	9.54	9.71	9.62
N_6	0.254	0.259	0.256	123.21	120.71	121.96	12.36	11.01	11.69	147.20	142.49	144.85	9.96	10.12	10.04
SEm±	0.008	0.008	0.005	2.91	3.04	2.11	0.26	0.31	0.20	3.01	3.36	2.26	0.18	0.18	0.13
CD (P=0.05)	NS	NS	NS	8.33	8.69	6.14	0.76	0.89	0.59	8.61	9.61	6.59	NS	NS	NS
CV (%)	10.79	10.71	-	8.59	9.10	-	7.70	10.08	-	7.34	8.33	-	6.47	6.39	-
Sulphur levels															
S_0	0.239	0.244	0.242	110.62	108.47	109.55	10.75	9.52	10.14	139.25	137.14	138.20	8.92	9.08	9.00
S_{20}	0.246	0.249	0.248	117.63	115.69	116.66	12.05	10.69	11.37	142.02	139.47	140.75	9.74	9.89	9.82
S_{40}	0.249	0.253	0.251	119.47	117.84	118.66	12.22	10.96	11.59	143.65	140.85	142.25	10.12	10.26	10.19
S_{60}-	0.250	0.255	0.253	122.59	120.99	121.79	12.61	11.46	12.04	144.12	141.62	142.87	10.19	10.39	10.29
SEm±	0.005	0.005	0.004	1.71	1.85	1.52	0.20	0.23	0.17	1.90	1.78	1.59	0.11	0.13	0.10
CD (P=0.05)	NS	NS	NS	4.89	5.27	4.27	0.56	0.66	0.49	NS	NS	NS	0.30	0.37	0.28
CV (%)	8.57	8.52	-	6.68	7.32	-	7.54	9.96	-	6.11	5.85	-	5.02	6.07	-

NS= Non significant

Symbols description in materials and methods