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Optimisation of Sesame (*Sesamum indicum* L.) Production through Integrated Nutrient Management

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ABSTRACT

A field experiment was conducted on sesame during semi-rabi season of 2014-15 in vertisols of Madhya Pradesh at the Research Farm, Project Coordinating Unit (Sesame and Niger), JNKVV, Jabalpur to study the impact of integrated application of chemical fertilizers along with organic manures and biofertilizer on growth, yield attributes, yield and economics of Sesame. The experiment was laid out in a randomized block design having three replications with twelve treatments. The crop growth was better with integrated application of 100% recommended dose of NPK through fertilizer (RDF), 75% RDN through FYM (25%), vermicompost (25%) and neem oil cake (25%). Similarly higher seed, stover and oil yield were recorded under application of 100% RDF + 75% RDN through FYM (25%) + VC (25%) + NOC (25%) which was at par with application of 150% RDF along with micronutrients (Zn and Fe) and *Azotobacter*. In terms of economics, integrated application of 150% RDF along with micronutrients (Zn and Fe) and *Azotobacter* fetched higher gross and net monetary return and also a higher B: C ratio of 1.72 as compared to other treatments.

Introduction

Sesame (*Sesamum indicum* L.) is one of the important oilseed crops in Indian agriculture and perhaps the oldest oilseed crop in the world. Due to presence of potent antioxidants, sesamum seeds are called as “the seeds of immortality”. Sesame seeds are rich source of food, nutrition, edible oil and bio-medicine. Its oil has excellent nutritional, medicinal, cosmetic and cooking qualities for which it is known as ‘the queen of oils’. It is cultivated on a large area in the states of Maharashtra, Uttar Pradesh, Rajasthan, Orissa, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, West Bengal, Gujarat, Karnataka, Kerala, Bihar, Assam and Punjab and to a limited extent, in Tripura and Himachal Pradesh. By virtue of its early maturing, sesame fits well into a number of multiple cropping systems either as a catch crop or a sequence crop in *rabi* and pre-*kharif* seasons. India ranks first in area, production and export of sesame in the world. Sesame ranks third in terms of total oilseed area and fourth in terms of total oilseed production in India. The average yield of sesame in India is very low (474 kg ha^{-1}) (Anonymous, 2015). But the productivity of sesame in general is much lower than its potential yield. Lower productivity is due to use of sub-optimal rate of fertilizer, poor management and cultivation of sesame in marginal and sub-marginal lands where deficiency of macronutrients such as nitrogen, phosphorus, potassium and micronutrient is predominant. This indicates the scope and need to increase the productivity of sesame. Integrated use of organic manures and biofertilizers along with chemical fertilizers in sesame helps maintaining stability in crop production, besides improving soil physical conditions (Deshmukh *et al.,* 2002 and Verma *et al.,* 2013). Keeping the above facts in view, the present investigation was under taken to find out the effects of diversified nutrient sources through integrated nutrient management on sesame.

Materials and Methods

Field experiment was conducted at Research Farm, Project Coordinating Unit (Sesame and Niger), JNKVV, Jabalpur (Madhya Pradesh) during *semi-rabi* season, 2014-15. The geographical location of the experimental site is situated in Kymore Plateau and Satpura Hills agroclimatic zone of Madhya Pradesh at 23.19^0N longitude and 79.94^0E latitude with an altitude of 412 m above MSL and the farm receives a total annual rainfall of 1380 mm in 69 rainy days.

The soil of the experimental site was clayey in texture (28.10 % sand, 21.30 % silt and 50.60 % clay). It was low in organic carbon (0.44 %), available nitrogen (209 kg/ha), medium in available phosphorus (19 kg/ha), but high in available potassium (328 kg/ha). The soil was nearly neutral in reaction (pH 7.4) and soluble salt concentration was also below harmful limit.

Experiment on sesame was laid out in a randomized block design having three replications with twelve treatments viz. T_1-100% RDF (Location specific), T_2-125% RDF, T_3-150% RDF, T_4-100% RDF + Micronutrients (20 kg/ha $ZnSO_4$ + 25 kg/ha $FeSO_4$) + *Azotobacter*, T_5-150% RDF + Micronutrients (20 kg/ha $ZnSO_4$ + 25 kg/ha $FeSO_4$) + *Azotobacter*, T_6-100% RDF + 50% RDN through FYM, T_7-100% RDF + 50% RDN through VC, T_8-100% RDF + 50% RDN through NOC, T_9-100% RDF + 50% RDN through [FYM (17%) + VC (17%) + NOC (16%)], T_{10}-100% RDF + 75% RDN through [FYM (25%) + VC (25%) + NOC (25%)], T_{11}-100% RDF + 100% RDN through [FYM (34%) + VC (33%) + NOC (33%)], T_{12}-100% RDF +FYM +VC + NOC (30:30:30% RDN, respectively) + *Azotobacter*. White seeded sesame variety TKG-55 was sown at a spacing of 30×10 cm^2. Before sowing sesame seeds were inoculated with *Azotobacter* @ 10 g/kg seeds. As per the treatments specification, FYM, vermicompost and neem oil cake were applied 10 days before sowing at the time of ploughing for thorough mixing with soil. The recommended dose of fertilizers (RDF) was 60 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha. Full dose of phosphorous, potassium, zinc and iron and half dose of nitrogen in the form of single super phosphate, muriate of potash, zinc sulphate, ferrous sulphate and urea, respectively were applied as basal during the time of sowing. The rest half of N was applied as top dressing at 30 days after sowing (DAS). Sesame was sown during second week of September in 2014 using a seed rate of 5 kg ha^{-1}. The crop was irrigated thrice during the entire growing period.

The data on growth attributes were collected at different growth stages and that of yield attributes as well as yield were recorded at harvest. Oil extraction was done by Soxhlet's extraction method. The data collected from the experiment at different growth stages was subjected to statistical analysis as described by Gomez and Gomez (1984). Economics was worked out by estimating the cost incurred and yields obtained from different treatments.

Results and Discussion

Growth attributes of sesame

The supplementation of chemical fertilizer by organic nutrient sources in different combinations induced marked variation in growth and yield attributes and yield of sesame (Table 1 and 2). The tallest plant at 90 DAS of sesame was recorded with T_8-100% RDF + 50% recommended dose of nitrogen through NOC which is closely followed by T_6-100% RDF + 50% recommended dose of nitrogen through FYM. These treatments recorded a significant higher plant height as compared to control treatment *i.e.* T_1 (100% RDF) where the plant height was minimum (71.90 cm). Similarly, the lowest number of branches at 90 DAS was observed under T_1 i.e. 100% RDF. However, it significantly increases in plots receiving integrated sources of nutrients being maximum with T_9-100% RDF + 50% RDN through FYM (17%) + VC (17%) + NOC (16%) closely followed by T_{10}-100% RDF + 75% RDN through FYM (25%) + VC (25%) + NOC (25%). LAI at 60 DAS of sesame was maximum (5.85) under T_7-100% RDF + 50% RDN through VC and T_{10}-100% RDF + 75% RDN through FYM (25%) + VC (25%) + NOC (25%) which are statistically at par with T_{11}-100% RDF + 100% RDN through FYM (34%) + VC (33%) + NOC (33%). However, the lowest value of LAI (4.76) was recorded under T_1-100% RDF. Plant height and number of branches plant^{-1} at 90 DAS and LAI at 60 DAS of sesame did not vary significantly among the treatments where chemical fertilizers were supplemented through different sources of organic manures along with *Azotobacter*.

Nutrient management in sesame through integration of chemical, organic sources as well as biofertilizers resulted in significant increase in dry matter production, crop growth rate and relative growth rate. The highest dry weight of sesame at 90 DAS was recorded with T_{10}-100% RDF + 75% RDN through FYM (25%) + VC (25%) + NOC (25%) which is statistically at par with T_{11}-100% RDF + 100% RDN through FYM (34%) + VC (33%) + NOC (33%). Similarly, the CGR and RGR at 30-60 DAS were found to be maximum (3.53 g m^{-2} day^{-1}and 11.41 g g^{-1} day^{-1}, respectively) under T_{12}-100% RDF +FYM +VC + NOC (30:30:30% RDN, respectively) + *Azotobacter*.

However, at 60-90 DAS of sesame maximum CGR and RGR were recorded under T_{10}-100% RDF + 75% RDN through [FYM (25%) + VC (25%) + NOC (25%). This significant increase in dry weight and growth rate of sesame due to integrated nutrient management might be due to more synthesis of amino acids, increase in chlorophyll content in growing region and improving the photosynthetic activity, ultimately enhancing cell division and thereby increased the crop growth rate. This was evinced through the studies of Dubey and Khan (1993). The results clearly indicate that integrated use of chemical fertilizer, organic manure and biofertilizer was better than application of organic or biofertilizer or chemical sources of nutrient alone. This may be due to supply of nutrients from diversified sources and prolonged availability of nutrients to the growing plants.

The beneficial role of free living nitrogen fixing microorganisms for enhancing plant growth through their ability in nitrogen fixation as well as the effect of their metabolite secretion on the crop may also be attributed for the same. Using organic manure to supplement chemical fertilizer with respect to N might have resulted in good supply of potassium also. These results are in agreement with Imayavaramban *et al.,* (2002), Jaishankar and Wahab (2005) and Verma *et al.*, (2012).

Table.1 Growth attributes of sesame as influenced by various nutrient management treatments

Treatments	Plant height (cm)	Branches/ plant	LAI	Dry weight (g m^{-2})	CGR (g m^{-2} day^{-1})		RGR (g g^{-1} day^{-1})	
					30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
T_1-100% RDF (Location specific)	71.90	3.83	4.76	250.24	2.51	3.49	10.52	7.84
T_2-125% RDF	76.03	3.85	4.97	264.38	2.55	3.71	10.05	7.91
T_3-150% RDF	77.90	3.96	5.17	290.45	2.92	3.88	10.12	7.41
T_4-100% RDF + Micronutrients + *Azotobacter*	74.30	3.88	5.64	276.63	2.72	3.85	10.23	7.82
T_5-150% RDF + Micronutrients + *Azotobacter*	72.17	4.32	5.45	328.46	3.05	4.75	9.80	8.23
T_6-100% RDF + 50% RDN through FYM	81.20	4.10	5.22	283.96	2.50	4.19	9.32	8.45
T_7-100% RDF + 50% RDN through VC	72.20	4.18	5.85	285.03	2.65	4.10	9.77	8.16
T_8-100% RDF + 50% RDN through NOC	81.30	4.49	5.77	293.66	2.61	4.26	9.25	8.27
T_9-100% RDF + 50% RDN through [FYM (17%) + VC (17%) + NOC (16%)]	78.20	4.52	5.42	296.49	3.11	4.15	11.32	7.88
T_{10}-100% RDF + 75% RDN through [FYM (25%) + VC (25%) + NOC (25%)]	79.77	4.50	5.85	352.36	3.37	5.28	10.67	8.65
T_{11}-100% RDF + 100% RDN through [FYM (34%) + VC (33%) + NOC (33%)]	75.83	3.98	5.84	344.42	3.46	4.81	10.58	7.85
T_{12}-100% RDF + FYM + VC + NOC (30:30:30% RDN, respectively) + *Azotobacter*	77.73	3.97	5.21	329.48	3.53	4.50	11.41	7.64
SEm±	2.18	0.21	0.29	4.20	0.03	0.09	0.23	0.14
C D(P=0.05)	6.39	0.63	0.85	12.32	0.10	0.27	0.68	0.41

RDF (Recommended dose of fertilizer) – 60 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha, RDN: Recommended dose of nitrogen, FYM : Farmyard manure, VC : Vermicompost, NOC : Neem oil cake

Table.2 Yield attributes and yield of sesame as influenced by various nutrient management treatments

Treatments	Number of capsules /plant	Number of seeds/ capsule	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Oil content (%)	Oil yield (kg/ha)
T_1-100% RDF (Location specific)	25.50	24.30	2.50	338	2622	11.40	47.10	159
T_2-125% RDF	27.56	25.40	2.70	362	2788	11.51	46.08	167
T_3-150% RDF	28.00	26.30	2.73	408	3072	11.75	46.81	191
T_4-100% RDF + Micronutrients + *Azotobacter*	29.00	25.60	2.71	386	2924	11.68	43.66	169
T_5-150% RDF + Micronutrients + *Azotobacter*	26.80	27.00	2.90	519	3506	12.92	45.77	238
T_6-100% RDF + 50% RDN through FYM	31.40	28.60	3.20	438	2902	13.12	43.34	190
T_7-100% RDF + 50% RDN through VC	26.45	25.80	2.60	451	2969	13.21	42.19	190
T_8-100% RDF + 50% RDN through NOC	29.48	25.45	2.75	463	3042	13.25	47.13	218
T_9-100% RDF + 50% RDN through [FYM (17%) + VC (17%) + NOC (16%)]	29.20	25.90	3.00	482	3143	13.33	47.54	229
T_{10}-100% RDF + 75% RDN through [FYM (25%) + VC (25%) + NOC (25%)]	30.80	26.70	3.21	523	3737	12.30	47.50	248
T_{11}-100% RDF + 100% RDN through [FYM (34%) + VC (33%) + NOC (33%)]	29.30	28.20	3.30	508	3632	12.29	44.96	228
T_{12}-100% RDF + FYM + VC + NOC (30:30:30% RDN, respectively) + *Azotobacter*	29.40	28.70	3.40	498	3561	12.28	44.61	222
SEm±	1.54	1.79	0.09	11.85	99.92	-	-	-
C D(P=0.05)	4.62	NS	0.27	34.70	292.53	-	-	-

Table.3 Economics of sesame as influenced by various nutrient management treatments

Treatments	Cost of cultivation (Rs/ha)	Gross monetary returns (Rs/ha)	Net monetary returns (Rs/ha)	B:C ratio
T_1-100% RDF (Location specific)	18335	24971	6636	1.36
T_2-125% RDF	18795	26734	7939	1.42
T_3-150% RDF	19255	30096	10841	1.56
T_4-100% RDF + Micronutrients + *Azotobacter*	21085	28482	7397	1.35
T_5-150% RDF + Micronutrients + *Azotobacter*	22005	38083	16078	1.72
T_6-100% RDF + 50% RDN through FYM	27335	32111	4776	1.17
T_7-100% RDF + 50% RDN through VC	21935	33054	11119	1.50
T_8-100% RDF + 50% RDN through NOC	21935	33931	11996	1.54
T_9-100% RDF + 50% RDN through [FYM (17%) + VC (17%) + NOC (16%)]	23771	35311	11540	1.48
T_{10}-100% RDF + 75% RDN through [FYM (25%) + VC (25%) + NOC (25%)]	26435	38478	12043	1.45
T_{11}-100% RDF + 100% RDN through [FYM (34%) + VC (33%) + NOC (33%)]	29207	37376	8169	1.27
T_{12}-100% RDF + FYM + VC + NOC (30:30:30% RDN, respectively) + *Azotobacter*	28055	36640	8585	1.30

Yield components of sesame

The data regarding yield attributes and yield of sesame are presented in Table 2. The highest numbers of capsules plant^{-1} of sesame were recorded in the treatment T_6-100% RDF + 50% RDN through FYM which was closely followed by T_{10}-100% RDF + 75% RDN through FYM (25%) + VC (25%) + NOC (25%). Different nutrient management treatments did not show any significant variation in case of number of capsules plant^{-1}.

The lowest test weight of sesame seeds were observed under T_1-100% RDF which gradually increased with application of nutrients through integrated sources being maximum under T_{12}-100% RDF +FYM +VC + NOC (30:30:30% RDN, respectively) + *Azotobacter* closely followed by T_{11}-100% RDF + 100% RDN through FYM (34%) + VC (33%) + NOC (33%). However, the number of capsules plant^{-1} and test weight of sesame did not vary significantly among the treatments where chemical fertilizers were supplemented through different sources of organic manures along with *Azotobacter*. The data on seed and stover yield per hectare revealed that the application of T_{10}-100% RDF + 75% RDN through FYM (25%) + VC (25%) + NOC (25%) recorded the highest seed yield (523 kg) and stover yield (3737 kg). Yield attributes and seed yield of sesame were statistically at par among the treatments involving integrated nutrient management.

The lowest seed and stover yield (338 and 2622 kg/ha) were observed with the application of 100% RDF. Data regarding harvest index represented in Table 2 revealed that the minimum HI was recorded under 100% RDF and maximum HI under T_9-100% RDF + 50% RDN through FYM (17%) + VC (17%) + NOC (16%). However, all the integrated nutrient management treatments were statistically at par with regard to HI. Application of 100% RDF + 75% RDN through FYM (25%) along with vermicompost (25%) and neem oil cake (25%) recorded the highest oil yield of sesame which was at par with the treatments involving integrated nutrient management and 150% RDF (Table 2). The treatment (T_{10})

recorded 55.97% higher oil yield of sesame than that of 100% RDF. The results corroborate the findings of Thiruppathi *et al.*, (2001) and Verma *et al.*, (2012).

Economics

The cost of sesame cultivation was highest due to integrated application of 100% RDF and 100% N through FYM (34%) along with VC (33%) and NOC (33%). Highest gross return from sesame cultivation was obtained with integrated application of 100% RDF + 75% RDN through FYM (25%) + VC (25%) + NOC (25%) closely followed by integrated application of 150% RDF along with Micronutrients and *Azotobacter*. Integrated application of fertilizer along with FYM, VC and NOC at various proportions gave higher gross return than use of fertilizer along with FYM or VC or NOC alone (Table 3). However, the advantage of maximum gross monetary returns was nullified due to higher variable cost of cultivation under T_{10}-100% RDF + 75% RDN through [FYM (25%) + VC (25%) + NOC (25%). The highest net return and B:C ratio (Rs. 16078 ha^{-1} and 1.72, respectively) were obtained from tretament 150% RDF along with Micronutrients and *Azotobacter*. The results corroborate the findings of Yadav *et al.*, (2009).

The data from this experiment revealed that integrated nutrient management involving the use of 100% RDF + 75% RDN through FYM (25%) + VC (25%) + NOC (25%) recorded the highest seed, stover and oil yield, but have a comparatively lower return. At the same time application of 150% RDF along with Micronutrients and *Azotobacter* recorded a higher gross and net return as well as the highest benefit-cost ratio. Thus it can be concluded that nutrient management through the integrated application of 150% RDF along with Micronutrients and *Azotobacter* is more remunerative followed by application of 100% RDF along with 75% RDN through FYM (25%), VC (25%) and NOC (25%).

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