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Influence of different combinations of NPK and micronutrients on nutritional status and quality parameters of sesame under loamy sand of Gujarat

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Abstract
A field study to evaluate the effect of different combinations of NPK and micronutrients on nutritional status and quality parameters of sesame was conducted at Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agriculture University, Sardarkrushinagar during summer 2019. The experiment consisted of four factors each having two levels viz., nitrogen (N1 - 50 kg N ha^{-1}, N2 - 75 kg N ha^{-1}), phosphorus (P1 - 25 kg P_2O_5 ha^{-1}, P2 - 50 kg P_2O_5 ha^{-1}), potassium (K0 - 0 kg K_2O ha^{-1}, K1 - 30 kg K_2O ha^{-1}) and micronutrients (M0 - 0 Kg $ZnSO_4$ + 0 kg $FeSO_4$, M1 - 10 Kg $ZnSO_4$ + 10 kg $FeSO_4$). Total sixteen treatment combinations were laid out in Randomized block design with factorial concept and replicated three times. Results revealed that application of nitrogen, phosphorus, potassium and micronutrients at higher level had a significant influence on the nutrient uptake and protein content in sesame. After harvest of crop, DTPA extractable zinc content in soil was significantly increased with the application of micronutrients over control. At the same time interaction effect between these nutrients were found to be non-significant.

Keywords: Loamy sand, nutrient uptake, micronutrients, NPK, sesame

1. Introduction
Sesame (*Sesamum indicum* L.) is one among the ancient oilseed crop that is cultivated in India. It can be cultivated in plains up to an altitude of 1300 m with the temperature of about 20 °C and above, and it is well suited in areas having warm humid climate with an annual rainfall of 500 mm. Sesame can be grown as *kharif, rabi* and summer crop but production and productivity is higher during summer season. Since it is a short duration crop, it fits well into various cropping sequence such as sole, intercrop or mixed crop. Nutrition is one of the important aspects of crop production. Nutrition of sesame remained controversial for a very long time (Okpara *et al.* 2007) [7]. The growing environment has a major role in nutritional status of sesame. Loamy sand of Gujarat is coarse textured and have several problems including poor ion exchange capacity, low soil organic carbon content, low nutrient and water retention capacity which can adversely affect the mobility of available nutrients and leads to deficiency of macro and micronutrients. Thus, sesame production is affected by various means.

As agriculture is becoming very intensive, there is an increase demand for nutrients in soil and plant system. Major reasons for this are the removal of nutrients exceeds application of nutrients, greater demand and pressure on the soil for readily usable form of plant nutrients and high yielding improved verities of sesame require regular supply of macro and micro nutrient elements for maintaining crop growth. So balanced fertilizer application and crop nutrition is essential for getting sustainable yield. Nitrogen, phosphorus and potassium are the primary macro nutrients applied to soil for enhancing the crop growth because these elements play a key role in photosynthesis, root growth, energy transformation in plants, disease and drought resistance and for enhancing crop quality. The micronutrients content in sesame seeds is in the order Fe>Cu>Zn>Mn (Suresh *et al.* 2013) [16]. Iron and zinc are the major micronutrients that have been reported deficient in Indian soil (Singh, 2008) [15]. Iron is the cofactor for large number of enzymes superoxide dismutase (SOD), catalase (CAT), peroxidase and nitrate reductase that catalyse lots of biochemical processes within plants and zinc has an important role in plant metabolism (Rout and Sahoo, 2015 Rudani *et al.* 2018) [12, 13]. Micronutrients deficiency is one of the prime factors responsible for low productivity of sesame. This is because micronutrients act as the limiting factor for uptake of other major nutrients (Heidari *et al.* 2011) [2].

Hence, inclusion of micronutrients in the fertilization programme is very essential for improving the quality and nutritional status of crop. Effect of individual elements like Fe and Zn on kharif sesame in light textured soil of North Gujarat has been studied so far, but the combined effect of these nutrients along with NPK on summer sesame has not been studied intensively. Hence, an attempt has been made to evaluate the effect of NPK and micronutrients on quality and nutritional aspects of sesame in loamy sand.

Materials and Methods

The field experiment was conducted during summer, 2019 at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, S.K.D. Agricultural University, Sardarkrushinagar, Banaskantha (Gujarat). Geographically, this place is located at 72°19' East longitude and 24°19' North latitude at 154.52 m above the mean sea level and situated in North Gujarat agro climatic zone of Gujarat state. Initial characteristics of surface soil was loamy sand in texture with slightly alkaline nature (pH 7.80) and fertility status of low available nitrogen, organic carbon, DTPA extractable Fe and Zn and medium in availability phosphorus and potash. The experiment was laid out in Randomized block design with factorial concept, consisted of four factors each having two levels of viz., nitrogen (N1 - 50 kg N ha^{-1}, N2 - 75 kg N ha^{-1}), phosphorus (P1 - 25 kg P_2O_5 ha^{-1}, P2 - 50 kg P_2O_5 ha^{-1}), potassium (K0 - 0 kg K_2O ha^{-1}, K1 - 30 kg K_2O ha^{-1}) and micronutrients (M0 - 0 Kg $ZnSO_4$ + 0 kg $FeSO_4$, M1 - 10 Kg $ZnSO_4$ + 10 kg $FeSO_4$). Total sixteen treatment combinations and replicated three times. After preparing the field by ploughing, furrows were opened and the total land area was divided into 48 plots of size 3.6 m x 5.0 m. After attaining proper field condition, nitrogen, phosphorus and potassium were applied as per the treatment to each plot in the form of urea, diammonium phosphate, muriate of potash, respectively. Iron and zinc were applied to the plots in the form of iron sulphate and zinc sulphate at the time of sowing. Healthy seeds of sesame cv. GT 3 were sown in the furrows with recommended seed rate (3 kg ha^{-1}). Full dose of phosphorus, potash, iron and zinc and half dose of nitrogen were applied as basal and the remaining at branching stage. Five plants were randomly selected from each net plot and labelled. These plant samples were harvested separately for post-harvest observations. After satisfactory drying, seeds were separated from the capsules plot wise by beating the plants manually. The plant samples were grinded and digested using di-acid mixture. The nutrients (N, P, K, Fe, Zn) content in seed and stover were determined based on the standard procedures. Quality characteristics like oil content (%) in seed was determined by Nuclear Magnetic Resonance (NMR) method as suggested by Tiwari *et al.* (1974) [18], protein content of the seed was estimated by multiplying a factor 6.25 with nitrogen content (%) in the seed determined by micro-Kjeldahls method (Waranke and Barber, 1973) [20]. A representative soil sample of 500g was collected from each net plot at 0 to 15 cm depth to analyse available N, P_2O_5, K_2O and DTPA extractable Fe and Zn content in soil. To know the most effective treatment, benefit: cost ratio (BCR) of each treatment was worked out by dividing gross realization with net realization. Data recorded during the investigation regarding the quality and chemical parameters were statistically analyzed using the factorial randomized block design as represented by Panse and Sukhatme (1985) [8]. The summery tables for effect of treatments had been worked out using standard error of difference and critical difference (C.D.) at 5 % level of probability and are noted in the respective table

Results and Discussions

The data (Table 1, 2, 3 & 4) shows the effect of different levels of nitrogen, phosphorus, potash and micronutrients (Fe and Zn) and their interaction effect on nutrient uptake, quality parameters of sesame at maturity and the nutrients status of soil after harvest of crop.

Effect of nitrogen

Different levels of nitrogen application had positively influenced the nutrient uptake by seed of sesame. Significantly higher nitrogen (27.35 kg/ha), potassium (5.91 kg/ha) and iron (63.46 kg/ha) uptake by seed was recorded with the application of higher dose of N @ 75 kg N ha^{-1} (N_2) over (N_1). However, application of nitrogen did not exert significant effect on phosphorus and zinc uptake by seed. A similar trend was observed in stover of sesame, except significance in the uptake of zinc which was 40.51 g/ha. Oil content in seed was not affected by the application of nitrogen, but protein content was high with higher dose of N @ 75 kg N ha^{-1} (N_2). Results showed in table 3 indicates that significantly higher protein content (19.94%) was recorded with the application of 75 kg N ha^{-1} (N_2) over N_1 (18.79 %). After the harvest of the crop available nitrogen content (155.88 kg/ha) in soil was also significantly increased with the application of higher level of nitrogen.

Nitrogen (N) is one of the most important nutrient element that accelerates the growth of the plant because it is a constituent of chlorophyll. Increase in nutrient uptake by sesame with higher level of nitrogen was probably due to enhanced availability of nitrogen which contributed to increase in leaf area, resulted in higher photo assimilation and thereby improving the nutrient content in seed and stover of sesame. These results are in conformity with the findings of Nayek *et al.* (2014) [6], Zenawi and Mizan (2019) [22]. Shakeri *et al.* (2015) [14] reported that increase in level of nitrogen fertilizer not only improved the crop yield but also protein yield and percentage. Hence the application of nitrogen in soil was effective in improving the nutrient uptake by plant.

Effect of phosphorus

Significantly higher nitrogen (26.97 kg/ha) and phosphorus (6.45 kg/ha) uptake by seed and phosphorus uptake (10.05 kg/ha) by stover of sesame was recorded by the application of 50 kg P_2O_5 ha^{-1} (P_2) over (P_1). Pearse *et al.* (2006) [9] reported that an increase in P supply had significantly increased the P concentration and uptake in plants. Maximum potassium uptake (5.86 kg/ha) was recorded under P_2 level. Similar results were recorded by Jat *et al.* (2020) [3] and Kumar *et al.* (2008) [4] in sesame. Moderate supply of phosphorus is required during the growing period of sesame because it improves the root growth of the plant and thereby increasing root to shoot ratio. Better the root growth more will be the uptake of other nutrients. These findings are in close agreement with those reported by Radwan *et al.* (2016) [10].

Application of different levels phosphorus did not produce any significant difference in protein and oil content of sesame seeds, at the same time there was no significant difference in the soil nutrient status after the harvest of the crop with the application of different levels of phosphorus. Win *et al.* (2010) [21] showed that crude protein content of the seed was not significantly influenced by the different P levels, although total protein production increased with increase in seed yield.

Table 1: Effect of different levels of NPK and micronutrients (Fe and Zn) on nitrogen, phosphorus, potassium, iron and zinc uptake by seed of sesame

Treatment	Uptake by seed				
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Fe (g ha^{-1})	Zn (g ha^{-1})
Nitrogen (kg N ha^{-1})					
N_1- 50	24.33	5.79	5.48	56.84	19.38
N_2- 75	27.35	6.29	5.91	63.46	21.03
S.Em ±	0.74	0.20	0.14	1.98	0.57
CD @ 0.05	2.13	NS	0.41	5.70	NS
Phosphorus (kg P_2O_5 ha^{-1})					
P_1-25	24.71	5.63	5.52	58.95	19.71
P_2- 50	26.97	6.45	5.86	61.35	20.71
S.Em ±	0.74	0.20	0.14	1.98	0.57
CD @ 0.05	2.13	0.57	NS	NS	NS
Potash (kg K_2 O ha^{-1})					
K_0 -No Potash	24.82	5.75	5.45	58.02	19.66
K_1 -30	26.86	6.31	5.94	62.28	20.76
S.Em ±	0.74	0.20	0.14	1.98	0.57
CD @ 0.05	NS	NS	0.41	NS	NS
Micronutrient (kg ha^{-1})					
M_0 -No micronutrients	24.85	5.91	5.51	56.05	19.35
M_1 -10 kg $ZnSO_4$ +10 kg $FeSO_4$	26.83	6.16	5.87	64.25	21.07
S.Em ±	0.74	0.20	0.14	1.98	0.57
CD @ 0.05	NS	NS	NS	5.70	1.66
Interaction					
NP, NK, NM, PK, PM, KM	NS	NS	NS	NS	NS
NPK, NPM, NKM, PKM	NS	NS	NS	NS	NS
NPKM	NS	NS	NS	NS	NS
CV (%)	14.02	16.20	12.50	13.77	13.90

Table 2: Effect of different levels of NPK and micronutrients (Fe and Zn) on nitrogen, phosphorus, potassium, iron and zinc uptake by stover of sesame

Treatment	Uptake by stover				
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Fe (g ha^{-1})	Zn (g ha^{-1})
Nitrogen (kg N ha^{-1})					
N_1- 50	20.87	9.39	17.38	597	37.71
N_2- 75	22.42	10.02	18.16	653	40.51
S.Em ±	0.40	0.22	0.28	18.73	0.88
CD @ 0.05	1.17	NS	NS	54.11	2.55
Phosphorus (kg P_2O_5ha^{-1})					
P_1-25	21.15	9.36	17.68	622	38.82
P_2-50	22.13	10.05	17.86	627	39.40
S.Em ±	0.40	0.22	0.28	18.73	0.88
CD @ 0.05	NS	0.65	NS	NS	NS
Potash (kg K_2 O ha^{-1})					
K_0 -No Potash	21.25	9.51	17.42	613	38.5
K_1 -30	22.03	9.90	18.12	636	39.72
S.Em ±	0.40	0.22	0.28	18.73	0.88
CD @ 0.05	NS	NS	NS	NS	NS
Micronutrient (kg ha^{-1})					
M_0 -No micronutrients	21.24	9.66	17.37	595	37.82
M_1 -10 kg $ZnSO_4$ +10 kg $FeSO_4$	22.04	9.76	18.17	654	40.40
S.Em ±	0.40	0.22	0.28	18.73	0.88
CD @ 0.05	NS	NS	NS	54.11	2.55
Interaction					
NP, NK, NM, PK, PM, KM	NS	NS	NS	NS	NS
NPK, NPM, NKM, PKM	NS	NS	NS	NS	NS
NPKM	NS	NS	NS	NS	NS
CV (%)	9.24	11.31	7.82	14.68	11.09

Effect of potassium

Application of potassium @ 30 kg K_2O ha^{-1} resulted in significantly higher potassium uptake (5.94 kg/ha) by seed over the control. Umer *et al.* (2008) reported that application of potassium fertilizers increased plant tissue concentration of K. However, potassium application had no effect on nutrient uptake by stover and on quality parameters of sesame. Available nitrogen, phosphorus, potassium and DTPA extractable iron and zinc content in soil improved after harvest of the crop but the application of potassium did not make any significant difference in nutrient status of soil since the soil of Gujarat have sufficient amount of potassium even without fertilizer application, results were in accordance with the findings of Ramamurthy *et al.* (2008) [11].

Table 3: Effect of different levels of NPK and micronutrients (Fe and Zn) on protein content and oil content in sesame seed

Treatment	Protein content in seed (%)	Oil content in seed (%)
Nitrogen (kg N ha^{-1})		
N_1-50	18.79	47.85
N_2-75	19.94	48.96
S.Em ±	0.32	0.39
CD @ 0.05	0.93	NS
Phosphorus (kg P_2O_5ha^{-1})		
P_1: 25	19.00	48.00
P_2: 50	19.73	48.81
S.Em ±	0.32	0.39
CD @ 0.05	NS	NS
Potash (kg K_2O ha^{-1})		
K_0 : No Potash	19.04	48.03
K_1 :30	19.69	48.78
S.Em ±	0.32	0.39
CD @ 0.05	NS	NS
Micronutrient (kg ha^{-1})		
M_0 : No micronutrients	19.08	48.08
M_1 :10 kg $ZnSO_4$ +10 kg $FeSO_4$	19.65	48.72
S.Em ±	0.32	0.39
CD @ 0.05	NS	NS
Interaction		
NP, NK, NM, PK, PM, KM	NS	NS
NPK, NPM, NKM, PKM	NS	NS
NPKM	NS	NS
CV (%)	8.19	4.01

Effect of micronutrients

Significantly higher iron (64.25 g/ha) and zinc (21.07 g/ha) uptake by seed and iron (654 g/ha) and zinc (40.40 g/ha) uptake by stover was recorded with the application of micronutrients @ 10 kg $ZnSO_4$ + 10 kg $FeSO_4$/ha over control. Zinc and iron play an important role in improving the photosynthetic ability and assimilating capacity of crop by being a component in various enzymatic and other biochemical reactions. This might be due to increase in presence available form of micronutrients iron and zinc (Fe^{2+} and Zn^{2+}) in soil, Similar results were also observed by Mankar *et al.* (2004) [5]. After harvest of crop, DTPA extractable zinc content (0.49 mg/kg) in soil was significantly increased with the application of micronutrients @ 10 kg $ZnSO_4$/ha + 10 kg $FeSO_4$/ha to sesame over control. According to Govindaraj *et al.* (2011) [1] iron (Fe) and zinc (Zn) are the trace elements that play important role in plant growth and they will improve plant nutrition and increase soil productivity.

Table 4: Effect of varying levels of NPK and micronutrients (Fe and Zn) on available N, P_2O_5, K_2O and DTPA extractable Fe and Zn content in soil after harvest of sesame

Treatment	Available			DTPA extractable	
	N(kgha^{-1})	P_2O_5(kgha^{-1})	K_2O(kgha^{-1})	Fe(mgkg^{-1})	Zn(mgkg^{-1})
Nitrogen (kg N ha^{-1})					
N_1- 50	150.87	36.18	180.54	4.88	0.45
N_2-75	155.88	36.80	182.53	5.00	0.48
S.Em ±	1.59	0.93	2.59	0.08	0.01
CD @ 0.05	4.60	NS	NS	NS	NS
Phosphorus (kg P_2O_5 ha^{-1})					
P_1-25	151.25	35.31	181.01	4.96	0.47
P_2-50	155.50	37.67	182.06	4.96	0.46
S.Em ±	1.59	0.93	2.59	0.08	0.01
CD @ 0.05	NS	NS	NS	NS	NS
Potash (kg K_2O ha^{-1})					
K_0 -No Potash	151.62	35.88	177.96	4.91	0.46
K_1 -30	155.12	37.10	185.11	4.97	0.47
S.Em ±	1.59	0.93	2.59	0.08	0.01
CD @ 0.05	NS	NS	NS	NS	NS
Micronutrient (kg ha^{-1})					
M_0 : No micronutrients	151.30	36.50	179.44	4.82	0.44
M_1 :10 kg $ZnSO_4$ +10 kg $FeSO_4$	155.37	36.31	183.63	5.06	0.49
S.Em ±	1.59	0.93	2.59	0.08	0.01
CD @ 0.05	NS	NS	NS	NS	0.03
Interaction					
NP, NK, NM, PK, PM, KM	NS	NS	NS	NS	NS
NPK, NPM, NKM, PKM	NS	NS	NS	NS	NS
NPKM	NS	NS	NS	NS	NS
CV (%)	5.10	12.49	6.99	8.34	12.82

Economics

Application of micronutrients (M_1) 10 kg $ZnSO_4.7H_2O$/ha + 10 kg $FeSO_4.7H_2O$/ha along with the recommended dose of NPK recorded the highest B:C ratio of 2.54 in sesame production, gross and net realization of 86264 Rs/ha and 52383 Rs/ha, respectively. Tiwari *et al*. (1995) [17] reported that the combined application of zinc sulphate and ferrous sulphate in soil excelled all the other treatments and had produced the highest yield thereby resulting in high benefit cost ratio.

Among the two nitrogen levels, higher gross and net realization of 86678 Rs/ha and 52407 Rs/ha and B:C ratio of 2.53 was obtained with N_2 (75 kg N /ha). In case of phosphorus application, higher gross and net realization of 86466 Rs/ha and 50627 Rs/ha and B:C ratio of 2.41 was obtained with P_2 level (50 kg P_2O_5 /ha). Application of potash (30 kg K_2O /ha) to sesame resulted in gross and net realization of 85964 Rs/ha and 34181 Rs/ha, respectively and B:C ratio of 2.51.

Table 5: Economics of different levels of nutrients

Treatment	Yield (kg/ha)		Gross realization (₹/ha)	Fixed cost (₹/ha)	Variable Cost (₹/ha)	Total cost (₹/ha)	Net realization (₹/ha)	BCR
	Seed	Stover						
Level of nitrogen (N)								
N_1 (50 kg N /ha)	809	1870	81835	33231	693	33924	47911	2.41
N_2 (75 kg N /ha)	857	1956	86678	33231	1040	34271	52407	2.53
Level of phosphorus (P)								
P_1 (25 kg P_2O_5 /ha)	810	1893	81946	33231	1347	34578	47368	2.37
P_2 (50 kg P_2O_5 /ha)	855	1933	86466	33231	2608	35839	50627	2.41
Levels of Potassium (K)								
K_0 (0 kg K_2O /ha)	815	1898	82449	33231	0	33231	49218	2.48
K_1 (30 kg K_2O /ha)	850	1929	85964	33231	950	34181	51783	2.51
Levels of Micronutrient (M)								
M_0 (0 kg $ZnSO_4.7H_2O$/ha + 0 kg $FeSO_4.7H_2O$/ha)	813	1898	82249	33231	0	33231	49018	2.47
M_1 (10 kg $ZnSO_4.7H_2O$/ha + 10 kg $FeSO_4.7H_2O$/ha)	853	1928	86264	33231	650	33881	52383	2.54
Seed Price: 100 Rs/kg Stalk Price: 0.50 Rs/kg								

Conclusion

Based on the results of research, it can be concluded that sesame crop should be fertilized with 75 kg N ha^{-1}, 50 kg P2O5 ha^{-1}, 30 kg K_2O ha^{-1} and 10 kg ZnSO4 + 10 kg FeSO4 ha^{-1} in loamy sand for obtaining better quality seeds with high nutrient status.

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