Original Research Article

Effect of Integrated Nutrient Management on Dynamics of Nutrient Availability at Various Intervals in Mustard (*Brassica juncea* L.) Crop

Abstract

A field experiment was conducted at College Farm, Agricultural College, Polasa, Jagtial, Professor Jayashankar Telangana State Agricultural University. The study was aimed at identifying effect of integrated nutrient management on nutrient availability in soil. The field experiment was laid out in randomized block design with nine treatments replicated thrice. The treatments includes T1: 100% Recommended dose of Fertilizer (RDF), T2: 100% RDF + FYM (Farm Yard Manure), T3: 100% RDF + FYM + Biofertilizer consortium, T4: 75% RDF, T5: 75% RDF + FYM, T6: 75% RDF + FYM + Biofertilizer consortium, T7: Soil Test Based (STB) NPK, T8: 75% STB NPK + FYM and T9: 75% STB NPK + FYM + Biofertilizer consortium. The results of the experiment revealed that integrated nutrient management significantly influenced the availability of various nutrients at different stages of the crop. Significantly higher nitrogen and its inorganic fractions, phosphorous, potassium and sulphur availability was recorded with the integrated application of 75% STB + FYM + Biofertilizer consortium which was comparable with application of Soil Test Based NPK, 100 % RDF + FYM + Biofertilizer consortium and 75% STB NPK + FYM. The lower available nitrogen, phosphorus, potassium, sulphur, ammonical and nitrate nitrogen were recorded under the treatment 75 % RDF.

Keywords: Indian Mustard, FYM, Biofertilizer consortium.

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Introduction

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In India, due to the lack of optimal nutrient utilization and improper management, the average yield of rapeseed mustard is only 1,089 kg ha^{-1} (Anonymous, 2014a). Productivity of rapeseed mustard is quite low due to cultivation on marginal land under rainfed conditions and optimal application of fertilizers. Extreme use of chemical fertilizers will damage the biological power of the soil, which must be prevented as all nutrient transformations was carried out through the soil microbial community. Intensive farming and the use of unbalanced and insufficient fertilizers, as well as limitations on the use of organic fertilizers

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not only make the soil lack of nutrients but also deteriorate soil health. The INM is a flexible method that minimizes use of chemical sources of nutrients and maximizes farmer's profits. Chemical fertilizers, organic manures, legumes, crop residues or wastes and biological fertilizers are the main component of INM. Oilseeds are the second largest agricultural commodity after cereals in India, producing 31.3 million tonnes under 24.65 M ha area (Agricultural Statistics at a Glance, 2018). Over the past 15 years, India's oilseed market has undergone tremendous changes, from being a net importing country in the 1980s to being self sufficient and becoming a net exporting country in the early 1990s. India is the world's third largest producer of rapeseed and mustard next to China and Canada. This crop accounts for nearly one-third of India's oil production, making it an important edible oil seed crop in the country. India accounts for 28.3 per cent and 12.0 per cent of the world's cropped area and production (Mhetre *et al*., 2019). In India, it is the third most important edible oil crop after soybean and groundnut, accounting for 27.8 per cent of the oil economy. The global production of mustard seed and its oil is approximately 38-42 MT and 12-14 MT, respectively. India is next to China (11-12 MT) and Europe (10-13 MT), producing about 6.9 MT of rapeseed mustard, making a significant contribution to the world mustard industry (Anonymous, 2014b). Indian soils are becoming deficient in N, P and K along with S due to intensive cultivation and use of high analysis fertilizers, under such situation organic manures can be exploited to boost the soil health condition vis-à-vis production of crops and to improve fertilizer use efficiency. Balanced nutrient management through the combined use of organic, inorganic and biological fertilizers is not only conducive to the sustainable production of crops, but also conducive to maintaining soil health (Singh and Sinsinwar, 2006). Investigations involving chemical fertilizers as well as organic and biological fertilizers as sources of supplementary nutrients for mustard are critical to the state's economy. Therefore, taking into account the increase in the demand and cost of chemical fertilizers, we are encouraged to plan field trials that use organic fertilizers and biological fertilizers together with chemical fertilizers to economically use the applied nutrients at a sustainable production level and maintain soil health.

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Materials and methods

A field experiment was carried out at College Farm of Agricultural College, Jagtial with mustard variety NRCHB-101 as a test crop during rabi, 2020. The experimental farm was located at 18º 50' 58" N latitude and 78º 56' 97" E longitude at an altitude of 243.4 m above mean sea level. The experiment was laid out in Randomized Block Design (RBD) with three replications which includes T1: 100% Recommended dose of Fertilizer (RDF), T2: 100% RDF + FYM, T3: 100% RDF + FYM + Biofertilizer consortium, T4: 75% RDF, T5: 75% RDF + FYM, T6: 75% RDF + FYM + Biofertilizer consortium, T7: Soil Test Based NPK, T8: 75% STB NPK + FYM and T9: 75% STB NPK + FYM + Biofertilizer consortium. Biofertilizer consortium includes Azotobacter + Phosphate Solubilizing Bacteria + Potassium Solubilizing Bacteria + Zinc Solubilizing Bacteria. Analysis of initial soil samples showed that the texture of the experimental soil was sandy clay loam having pH 7.85, EC 0.18 dSm^{-1}, organic carbon 0.50% (Walkley and Black's method), low available nitrogen content 196 kg ha^{-1} (Alkaline permanganate method, Subbiah and Asija, 1956), high in available phosphorus content 26.6 kg ha^{-1} (0.5 M $NaHCO_3$ extractable, Olsen *et al.*, 1954) high in available potassium content 360 kg ha^{-1} (Ammonium acetate extractable flame photometer, Jackson, 1973) and medium in available sulphur 26.8 kg ha^{-1} (Williams and Steinberg, 1959). Nitrogen fractions were analysed by extraction with potassium chloride followed by distillation with kelplus apparatus. A recommended dose of fertilizer for mustard was Nitrogen @ 60 kg ha^{-1}, Phosphorous @ 40 kg ha^{-1} and Potassium @ 40 kg ha^{-1}. The N, P and K fertilizers were applied in the form of urea (46% N), single super phosphate (16% P_2O_5) and, muriate of potash (60% K_2O), respectively. Phosphorus, potassium and half of N were applied as basal dose at the time of sowing of crop and remaining half dose of nitrogen applied flowering stage of mustard (55-60 DAS). In soil test based treatment 78 kg N ha^{-1}, 28 kg P_2O_5 ha^{-1} and 28 kg K_2O ha^{-1} was applied. Biofertilizers and FYM as per treatment were applied to soil before sowing of mustard. Bacteria inoculums used in this study were obtained from Biofertilizer unit, College of Agriculture, Rajendranagar. It includes Azotobacter + Phosphate Solubilizing Bacteria + Potassium Solubilizing Bacteria + Zinc Solubilizing Bacteria).

Results and discussion

1. Effect of integrated nutrient management on available nitrogen of soil during crop growth period.

Available nitrogen content in soil was significantly influenced by integrated nutrient management, data pertaining to soil available N (kg ha^{-1}) as influenced by different treatments of integrated nutrient management at 15, 30, 45, 60 DAS and at harvest are presented in Table 1. Available nitrogen content at 15 DAS was recorded significantly higher under 75% STB NPK + FYM + Biofertilizer consortium (265 kg ha^{-1}) which was on par with

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Soil Test Based STB NPK (258 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (248 kg ha^{-1}) and 75 % STB NPK + FYM (243 kg ha^{-1}). The lower available N of 180 kg ha^{-1} was recorded with 75 % RDF. At 30 DAS, significantly the higher available N of 229 kg ha^{-1} was recorded with application of 75% STB + FYM + Biofertilizer consortium which was however comparable with application of Soil Test Based NPK (222 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (213 kg ha^{-1}) and 75 % RDF + FYM (207 kg ha^{-1}). Further it was observed that lower available N of 148 kg ha^{-1} was recorded in the treatment 75 % RDF. Similar trend was also observed at 45 and 60 DAS. The ranges of available N were 119 to 208 and 108 to 209 kg ha^{-1} at 45 and 60 DAS, respectively. At harvest, the results revealed that higher available N was recorded with the integrated application of 75% STB NPK+ FYM + Biofertilizer consortium (221 kg ha^{-1}) which was on par with Soil Test Based NPK which recorded available N of 210 kg ha^{-1}, 100 % RDF + FYM + Biofertilizer consortium (207 kg ha^{-1}) and 75% RDF + FYM (206 kg ha^{-1}). The lower available N of 130 kg ha^{-1} was recorded under the treatment of 75 % RDF.

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Table 1. Effect of integrated nutrient management on available nitrogen of soil (kg ha^{-1}) during crop growth period.

Treatment	15 DAS	30 DAS	45 DAS	60 DAS	A.H
100% RDF	192	163	136	131	144
100% RDF+ FYM	222	194	173	163	198
100% RDF+ FYM+ BC	248	213	196	191	207
75 % RDF	180	148	119	108	130
75 % RDF + FYM	199	163	144	140	156
75 % RDF + FYM+ BC	212	189	163	160	168
STB NPK	258	222	200	201	210
75% STB NPK+FYM	243	207	183	187	206
75% STB NPK+FYM + BC	265	229	208	209	221
Mean	224	192	169	165	181
Sem±	9.90	7.74	8.98	7.48	7.19
CD (P=5)	30.0	23.4	27.2	22.6	21.8
CV	7.64	6.98	9.20	7.83	6.87

Higher available nitrogen under 75% STB NPK+ FYM + Biofertilizer consortium treatment and other INM treatments may be due to effect of FYM applied, which might improve microbial population rapidly, facilitated the conversion of soil native organic nitrogen to mineral nitrogen (Rajkhowa *et al.*, 2003), reduced the loses of applied mineral nitrogen (Dwivedi *et al*., 2016) by, biological nitrogen fixation by Azotobacter in soil (Banerjee *et al.*, 2011). Soil test based NPK application in soil also recorded higher available nitrogen content

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in soil as the initial soil nitrogen content comes under low category (186 kg ha^{-1}), hence under this treatment 30 % extra nitrogen was applied to soil. Hence, percent contribution from fertilizer will be higher than soil source in any other treatment, besides higher amount of N applied at 60 DAS as split might maintained higher amount of nitrogen in soil (Verma *et al*., 2010). Critical observations of the data at different stages of crop revealed that soil available nitrogen declined from 15 DAS to 60 DAS and then it has increased slightly in after harvest soil samples. Up to 60 DAS mustard crop crosses through branching (30- 35 DAS), flowering stages (45-50 DAS) and siliqua formation (50-55 DAS) which requires huge amount of nutrients (Mukherjee, 2016). Hence, crop might have taken up huge amount of nitrogen from soil resulted in lower soil nitrogen. After that, the crop comes to a maturity stage where the crop lifts fewer nutrients and higher root exudation which contains amino acids. (Yang *et al*., 2015) decomposition of dead roots might have improved available N resulted in significantly higher available N content at the maturity stage. When initial soil N compared with after harvest samples, 75% STB+FYM + Biofertilizer consortium, STB, 75% STB+FYM, 100% RDF+FYM + Biofertilizer consortium and 100% RDF+FYM treatments recorded higher available N. This might be due to slow mineralization, slow release of nitrogen from the organic manures and less loss of nitrogen due to leaching (Shilpashree *et al*., 2012), biological N fixation (Das *et al*., 2010), higher dose of N application. On the other hand, sole inorganic fertilizers (100% RDF, 75% RDF), low fertilizers with FYM (75% RDF+FYM, 75% RDF+ FYM+ Biofertlizer consortium) recorded lower values. This might be due to lower N applied could not satisfied the requirement of crop and the crop has utilized soil native nitrogen.

2. Effect of integrated nutrient management on available phosphorus of soil during crop growth period.

Integrated nutrient management had significantly influenced the available phosphorus content in soil, data pertaining to available P (kg ha^{-1}) as influenced by different treatments of integrated nutrient management at 15, 30, 45, 60 DAS and at harvest are presented in Table 2. Available phosphorus content at 15 DAS was recorded significantly higher under 75% STB + FYM + Biofertilizer consortium (42.8 kg P ha^{-1}) which was on par with Soil Test Based NPK (41.7 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (40.1 kg ha^{-1}) and 75% STB NPK + FYM (39.9 kg ha^{-1}). Lower available phosphorus of 28.0 kg ha^{-1} was recorded with 75 % RDF. Similar trend was also observed at 30 and 45 DAS. The ranges of available phosphorus were 23.8 to 38.9 and 22.3 to 35.7 kg ha^{-1} at 30 and 45 DAS, respectively. At 60

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DAS, significantly higher available phosphorus of 37.3 kg P ha^{-1} was recorded with application of 75% STB + FYM + Biofertilizer consortium which was comparable with application of Soil Test Based NPK (36.7 kg P ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (34.8 kg P ha^{-1}) and 75 % STB NPK RDF + FYM (33.7 kg ha^{-1}). Further it was observed that lower available phosphorus of 23.5 kg P ha^{-1} was recorded in the treatment 75 % RDF. At harvest, the results revealed that higher available phosphorus was recorded with the integrated application of 75% STB NPK+ FYM + Biofertilizer consortium (38.6 kg ha^{-1}) which was on par with Soil Test Based NPK which recorded available phosphorus of 37.6 kg ha^{-1}, 100 % RDF + FYM + Biofertilizer consortium (35.5 kg ha^{-1}) and 75% RDF + FYM (35.3 kg ha^{-1}). The lower available phosphorus of 24.7 kg ha^{-1} was recorded under the treatment 75 % RDF. Application of soil test based recommended fertilizers (75% STB) with FYM and biofertillizers increased the availability of phosphorus in the soil.

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Table 2. Effect of integrated nutrient management on available phosphorus of soil (kg P ha^{-1}) during crop growth period.

Treatment	15 DAS	30 DAS	45 DAS	60 DAS	A.H
100% RDF	30.7	26.3	24.2	24.7	25.3
100% RDF+ FYM	36.7	32.0	29.6	30.9	31.4
100% RDF+ FYM+ BC	40.1	35.1	33.2	34.8	35.5
75 % RDF	28.0	23.8	22.3	23.5	24.7
75 % RDF + FYM	31.1	28.1	24.3	24.9	25.7
75 % RDF + FYM+ BC	34.0	30.9	27.9	29.0	30.1
STB NPK	41.7	37.5	34.5	36.7	37.6
75% STB NPK+FYM	39.9	34.3	31.7	33.7	35.3
75% STB NPK+FYM + BC	42.8	38.9	35.7	37.3	38.6
Mean	36.1	31.9	29.3	30.6	31.6
Sem±	1.78	1.77	1.43	1.49	1.52
CD (P=5)	5.40	5.35	4.31	4.52	4.60
CV	8.55	9.61	8.43	8.44	8.35

This could be due to protective mechanism of FYM by reducing P fixation by covering the surfaces of sesquioxides (Parihar, 2016 and Singh and Pal, 2011) and it also increases the availability of nutrients by forming the organics chelates which has higher stability with organics ligands, which have lower susceptibility to adsorption, fixation and precipitation in soil. The results of present investigation are in line with the finding of Sahoo (2013), Patil *et al*. (2012), Sarma and Chakravarty (2012), Vidyavathi *et al*. (2012) and Das *et al*. (2010). Besides, FYM might have involved in increasing the labile P in soil through complexing of cations like Ca^{2+} and Mg^{2+} which are responsible for fixation of phosphorus (Bajpai *et al*.,

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2006). Critical observations of the data at different stages of crop revealed that available phosphorus declined from 15 DAS to 45 DAS, and then it has increased slightly at 60 DAS after harvest soil samples. When crop comes to maturity stage where crop lifts less nutrients, increase in the phosphorus availability in experimental soil in at harvest of the crop might be due to solubilization of the native P in soil through the release of various organic acids during the decomposition of dead plant roots and organic matter in soil (Rajkhowa *et al*., 2003). Integrated application of farmyard manure along with phosphatic fertilizers reduces the fixation of water-soluble phosphorus, and the effect of microorganisms like phosphorus solubilizing bacteria increases the mineralization of organic phosphorus, resulting in an increase in available phosphorus. The results of the present investigation are in agreement with the findings by Sahoo (2013) and Mohapatra and Dixit (2010). When initial soil P content compared with after harvest samples, 75% STB+FYM + Biofertilizer consortium, STB, 75% STB NPK +FYM, 100% RDF+FYM + Biofertilizer consortium, 100% RDF+FYM and 75% RDF +FYM + Biofertilizer consortium treatments recorded higher available P. This might be due to P mineralization of FYM, solubilization of native and fixed P by phosphorus solubilizing microorganisms. On the other hand, sole inorganic fertilizers (100% RDF, 75% RDF), low dose fertilizers with FYM (75% RDF+FYM) recorded lower values.

3. Effect of integrated nutrient management on available potassium of soil during crop growth period.

Available potassium content in soil was significantly influenced by integrated nutrient management, data pertaining to available potassium (kg ha^{-1}) as influenced by different treatments of integrated nutrient management at 15, 30, 45, 60 DAS and at harvest are presented in Table 3. Available potassium content at 15 DAS was recorded significantly higher under 75% STB NPK + FYM + Biofertilizer consortium (403 kg ha^{-1}) which was on par with Soil Test Based NPK (392 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (388 kg ha^{-1}) and 75 % STB NPK + FYM (377 kg ha^{-1}). The lower available potassium of 315 kg ha^{-1} was recorded with 75 % RDF. At 30 DAS, significantly higher available potassium of 388 kg ha^{-1} was recorded with application of 75% STB NPK + FYM + Biofertilizer consortium which was comparable with application of Soil Test Based NPK (382 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (381 kg ha^{-1}) and 75 % STB NPK + FYM (369 kg ha^{-1}). Further it was observed that lower available potassium of 299 kg ha^{-1} was recorded in the treatment 75 % RDF. Similar trend was also observed at 45 and 60

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DAS. The ranges of available potassium were 285 to 376 and 280 to 371 kg ha^{-1} at 45 and 60 DAS, respectively. At harvest available potassium content in soil varied from 319 kg ha^{-1} to 393 kg ha^{-1}. Further observation of data revealed that higher available potassium was recorded with the integrated application of 75% STB NPK+ FYM + Biofertilizer consortium (393 kg ha^{-1}) which was on par with Soil Test Based NPK which recorded available potassium of 387 kg ha^{-1}, 100 % RDF + FYM + Biofertilizer consortium (380 kg ha^{-1}) and 75% STB NPK + FYM (373 kg ha^{-1}). Lower available potassium of 319 kg ha^{-1} was recorded under the treatment 75 % RDF.

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Table 3. Effect of integrated nutrient management on available potassium of soil (kg ha^{-1}) during crop growth period.

Treatment	15 DAS	30 DAS	45 DAS	60 DAS	A.H
100% RDF	322	308	298	291	327
100% RDF+ FYM	354	344	332	327	356
100% RDF+ FYM+ BC	388	381	365	357	380
75 % RDF	315	299	285	280	319
75 % RDF + FYM	339	317	307	302	333
75 % RDF + FYM+ BC	340	329	317	318	346
STB NPK	392	382	368	361	387
75% STB NPK+FYM	377	369	355	346	373
75% STB NPK+FYM + BC	403	388	376	371	393
Mean	359	346	334	328	357
Sem±	15.4	14.0	14.0	13.7	12.8
CD (P=5)	46.6	42.4	42.4	41.4	38.7
CV	7.42	7.01	7.26	7.22	6.21

The application of organic fertilizers such as FYM leads to a decrease in fixed potassium, which may increase the potassium content due to the direct addition to the available potassium pools of the soil (Parihar, 2016 and Thakur *et al.*, 2011) and increased K availability might be from K bearing minerals by organic acids released during decomposition of FYM (Maurya *et al.*, 2017 and Singh *et al.*, 2006). Most of the nutrients in the simple cation form present in the soil at any time are exchangeable forms and are associated with the clay minerals and the organic part of the soil, where these can be quickly exchanged with the cations in the soil solution. These results are similar to the findings of Sahoo (2013) and Banerjee *et al.* (2011). The data at different stages of crop revealed that available potassium was declined from 15 DAS to 60 DAS, and then it has increased slightly in after harvest soil samples. Up to 60 DAS mustard crop crosses through branching (30-35 DAS), flowering stages (45-50 DAS) and siliqua formation (50-55 DAS) which requires huge

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amount of nutrients for translocation of photosynthates (Mukherjee, 2016). Hence, crop might have taken up huge amount of potassium from soil resulted in lower soil potassium. The increase of available potassium due to organic manures application might be the result of additional K supplied through organics and solubilizing action of certain organic acids produced during the process of decomposition and its greater capacity to hold K in the available form (Yaduvanshi, 2001). Solubilization of native potassium might have contributed to increase in available potassium content of soil (Gajghane *et al*., 2015). Increase in available K due to application of organic manures might be attributed to direct addition of K to available pool of soil K. The beneficial effect of organic sources on available K might also be attributed to the reduction of K fixation and its release in to soil due to interaction of organic matter with clay besides direct addition of potassium to the available K pool of soil (Kamble *et al*., 2018).

4. Effect of integrated nutrient management on available sulphur of soil during crop growth period

Integrated nutrient management significantly influenced the available sulphur content in soil, data pertaining to soil available S (kg ha^{-1}) as influenced by different treatments of integrated nutrient management at 15, 30, 45, 60 DAS and at harvest are presented in Table 4. Available sulphur content at 15 DAS was recorded significantly higher under 75% STB NPK + FYM + Biofertilizer consortium (45.5 kg ha^{-1}) which was on par with Soil Test Based STB NPK (43.6 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (42.6 kg ha^{-1}) and 75% STB NPK + FYM (41.5 kg ha^{-1}). Lower soil available sulphur of 29.1 kg ha^{-1} was recorded with 75 % RDF. Similar trend was also observed at 30 and 45 DAS. The ranges of available sulphur varies from 26.0 to 40.0 and 21.2 to 36.4 kg ha^{-1} at 30 and 45 DAS, respectively. At 60 DAS, significantly the higher available sulphur of 31.7 kg ha^{-1} was recorded with application of 75% STB NPK + FYM + Biofertilizer consortium which was comparable with application of Soil Test Based NPK (30.5 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (29.7 kg ha^{-1}) and 75 % STB NPK RDF + FYM (28.1 kg ha^{-1}). Further it was observed that lower available sulphur of 17.6 kg ha^{-1} was recorded in the treatment 75 % RDF. On observation of data at harvest, the results revealed that higher available sulphur was recorded with the integrated application of 75% STB NPK + FYM + Biofertilizer consortium (40.0 kg ha^{-1}) which was on par with Soil Test Based NPK which recorded available sulphur of 38.6 kg ha^{-1}, 100 % RDF + FYM + Biofertilizer consortium (37.8 kg ha^{-1}) and 75% STB

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NPK RDF + FYM (35.5 kg ha^{-1}). The lower available sulphur of 24.3 kg ha^{-1} was recorded under the treatment 75 % RDF.

Table 4. Effect of integrated nutrient management on available sulphur of soil (kg ha^{-1}) during crop growth period.

Treatment	15 DAS	30 DAS	45 DAS	60 DAS	A.H
100% RDF	31.7	27.2	23.2	18.8	25.6
100% RDF+ FYM	38.5	34.9	30.1	26.1	34.4
100% RDF+ FYM+ BC	42.6	37.3	33.8	29.7	37.8
75 % RDF	29.1	26.0	21.2	17.6	24.3
75 % RDF + FYM	33.6	28.3	24.4	19.7	26.1
75 % RDF + FYM+ BC	37.0	30.0	27.6	22.3	30.5
STB NPK	43.6	38.9	35.4	30.5	38.6
75% STB NPK+FYM	41.5	36.7	32.4	28.1	35.5
75% STB NPK+FYM + BC	45.5	40.0	36.4	31.7	40.0
Mean	29.1	26.0	21.2	17.6	24.3
Sem±	1.65	1.53	1.69	1.30	1.59
CD (P=5)	4.99	4.63	5.10	3.93	4.81
CV	7.49	7.96	9.93	9.03	8.47

Further observations of the data revealed that at different stages of crop the available sulphur declined from 15 DAS to 60 DAS, and then it has increased slightly in after harvest soil samples. Sulphur has not been applied as straight fertilizer but along with phosphatic fertilizer different grades of sulphur has also applied to the treatments. This could be the reason for higher S content at 15 DAS. Up to 60 DAS mustard crop crosses through branching (30-35 DAS), flowering stages (45-50 DAS) and siliqua formation (50-55 DAS) which requires huge amount of nutrients (Mukherjee, 2016). Sulphur is important crop nutrient for mustard crop yield and to produce quality oil. Increased sulphur content in post harvest soils might be due to addition of FYM increases the availability of native sulphur in soil and FYM is also considered as a good source of sulphur which adds sulphur to the soil causes increase in available pool of sulphur in soil. The current findings are in conformity with Parmar et al. (2020) and Mohapatra and Dixit (2010). Application of sulphur with organics shows positive influence on availability of sulphur in soil

5. Effect of integrated nutrient management on ammonical and nitrate nitrogen of soil during crop growth period.

At 15 DAS, significantly higher ammonical nitrogen of 95.4 kg ha^{-1} and nitrate nitrogen of 58.2 kg ha^{-1} was recorded with the application of 75% STB NPK + FYM + Biofertilizer

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consortium which was comparable to application of Soil Test Based NPK (91.3 and 56.0 kg ha^{-1} NH_4-N and NO_3-N respectively), 100 % RDF + FYM + Biofertilizer consortium (88.1 and 53.8 kg ha^{-1} NH_4-N and NO_3-N respectively) and 75 % STB NPK + FYM (85.8 and 50.5 kg ha^{-1} NH_4-N and NO_3-N respectively). Further it was observed that lower ammonical nitrogen of 57.0 kg ha^{-1} and nitrate nitrogen of 32.0 kg ha^{-1} was recorded in the treatment 75 % RDF (Table 5 and Table 6). Ammonical nitrogen content at 30 DAS was recorded significantly higher under 75% STB + FYM + Biofertilizer consortium (86.5 kg ha^{-1}) which was on par to Soil Test Based NPK (83.5 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (78.9 kg ha^{-1}) and 75 %STB NPK + FYM (76.4 kg ha^{-1}). The lower ammonical nitrogen of 48.2 kg ha^{-1} was recorded with 75 % RDF. At 30 DAS nitrate nitrogen content was recorded significantly higher under 75% STB + FYM + Biofertilizer consortium (51.7 kg ha^{-1}) which was on par with Soil Test Based NPK (49.8 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (47.6 kg ha^{-1}) and 75 % STB NPK + FYM (45.8 kg ha^{-1}). Lower nitrate nitrogen of 28.8 kg ha^{-1} was recorded with 75 % RDF. At 45 DAS ammonical nitrogen content in soil varied from 41.6 kg ha^{-1} to 79.1 kg ha^{-1} and nitrate nitrogen content ranges from 25.9 to 45.2 kg ha^{-1}. Observation of data revealed that higher ammonical nitrogen was recorded with the integrated application of 75% STB NPK + FYM + Biofertilizer consortium (79.1 kg ha^{-1}) which was on par with Soil Test Based NPK which recorded ammonical nitrogen of 76.3 kg ha^{-1}, 100 % RDF + FYM + Biofertilizer consortium (72.3 kg ha^{-1}) and 75% STB NPK + FYM (69.6 kg ha^{-1}). The lower ammonical nitrogen of 41.6 kg ha^{-1} was recorded under the treatment 75 % RDF (Table 5). At 45 DAS nitrate nitrogen content was significantly higher under 75% STB NPK + FYM + Biofertilizer consortium (45.2 kg ha^{-1}) which was on par with Soil Test Based NPK (42.8 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (41.2 kg ha^{-1}) followed by 75 % STB NPK + FYM (39.3 kg ha^{-1}). The lower nitrate nitrogen of 25.9 kg ha^{-1} was recorded with 75 % RDF (Table 6). At 60 DAS, significantly higher ammonical nitrogen of 78.3 kg ha^{-1} and nitrate nitrogen of 44.2 kg ha^{-1} was recorded with application of 75% STB NPK + FYM + Biofertilizer consortium which was comparable to application of Soil Test Based NPK (75.3 kg ha^{-1}) followed by 100 % RDF + FYM + Biofertilizer consortium (72.0 kg ha^{-1}) and 75 % STB NPK + FYM (68.5 kg ha^{-1}). Further it was observed that lower ammonical nitrogen of 33.6 kg ha^{-1} was recorded in the treatment 75 % RDF (Table 5). At 60 DAS nitrate nitrogen content was recorded significantly higher under 75% STB NPK + FYM + Biofertilizer consortium (44.2 kg ha^{-1}) which was on par with Soil Test Based NPK (42.2 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (39.8 kg ha^{-1}) followed by 75 % RDF + FYM (39.2 kg ha^{-1}). Lower

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nitrate nitrogen of 21.8 kg ha^{-1} was recorded with 75 % STB NPK (Table 6). At harvest ammonical nitrogen content in soil varied from 48.9 kg ha^{-1} to 93.1 kg ha^{-1} and nitrate nitrogen varied from 28.5 to 53.6 kg ha^{-1}. Observation of data at harvest shows significantly higher ammonical nitrogen content of (93.1 kg ha^{-1}) was recorded in treatment 75% STB NPK + 5 t ha^{-1} FYM + Biofertilizer consortium @ 5 kg which was comparable with the treatment receiving Soil Test Based NPK which recorded (89.9 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (85.7 kg ha^{-1}) and 75 % STB NPK + FYM (82.8 kg ha^{-1}). Further it was observed that lower ammonical nitrogen of 48.9 kg ha^{-1} was recorded in the treatment of 75 % RDF (Table 5). At harvest nitrate nitrogen content was significantly higher under 75% STB NPK + FYM + Biofertilizer consortium (53.6 kg ha^{-1}) which was on par with Soil Test Based NPK (51.2 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (48.9 kg ha^{-1}) followed by 75 % STB NPK + FYM (46.6 kg ha^{-1}). Lower nitrate nitrogen of 28.5 kg ha^{-1} was recorded with 75 % RDF (Table 6).

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Table 5. Effect of integrated nutrient management on ammonical nitrogen soil (kg ha^{-1}) during crop growth period.

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Treatment	15 DAS	30 DAS	45 DAS	60 DAS	A.H
100% RDF	62.5	53.4	46.5	40.2	54.8
100% RDF+ FYM	78.7	67.1	62.6	61.6	75.3
100% RDF+ FYM+ BC	88.1	78.9	72.3	72.0	85.7
75 % RDF	57.0	48.2	41.6	33.6	48.9
75 % RDF + FYM	67.7	57.5	50.4	44.1	61.1
75 % RDF + FYM+ BC	70.5	60.9	54.1	52.4	67.4
STB NPK	91.3	83.5	76.3	75.3	89.9
75% STB NPK+FYM	85.8	76.4	69.6	68.5	82.8
75% STB NPK+FYM + BC	95.4	86.5	79.1	78.3	93.1
Mean	77.4	68.0	61.4	58.5	73.2
Sem±	3.95	3.53	3.59	3.68	4.29
CD (P=5)	11.9	10.7	10.9	11.1	13.0
CV	8.83	8.98	10.1	10.9	10.2

Higher ammonical nitrogen observed under INM treatments may be due to an increased rate of mineralization of FYM in the soil which was enhanced by the addition of FYM and hence caused an increase in NH_4-N in the soil. Besides, application of inorganic fertilizers favours the buildup of ammonical nitrogen in soil (Yadav and Singh, 1991). Sole inorganic fertilizer applied treatments like 100% RDF and 75% RDF recorded lower NH4-N, may be due to leaching losses. Higher NO_3-N was also recorded under INM treatments may be due to

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increased microbial activity increase in soil pH which might have enhanced nitrification process with a reduction in leaching losses. The present findings are in line with the results of Krishnaprabu (2020) and Shilpashree *et al*. (2012).

Table 6. Effect of integrated nutrient management on nitrate nitrogen soil (kg ha^{-1}) during crop growth period.

Treatment	15 DAS	30 DAS	45 DAS	60 DAS	A.H
100% RDF	33.6	30.0	27.7	24.2	31.2
100% RDF+ FYM	45.3	40.4	36.1	34.1	41.9
100% RDF+ FYM+ BC	53.8	47.6	41.2	39.8	48.9
75 % RDF	32.0	28.8	25.9	21.8	28.5
75 % RDF + FYM	36.3	32.9	29.4	27.2	33.6
75 % RDF + FYM+ BC	44.3	36.7	32.2	30.0	36.5
STB NPK	56.0	49.8	42.8	42.2	51.2
75% STB NPK+FYM	50.5	45.8	39.3	39.2	46.6
75% STB NPK+FYM + BC	58.2	51.7	45.2	44.2	53.6
Mean	45.5	40.4	35.5	33.6	41.3
Sem±	3.35	2.66	2.65	2.66	2.46
CD (P=5)	10.1	8.04	8.01	8.05	7.43
CV	12.7	11.4	12.9	13.7	10.3

Conclusions

Available nutrients viz., N, P, K and S were also significantly influenced by integrated nutrient management practices. The treatment receiving 75% STB + FYM + Biofertilizer Consortium maintained significantly higher available nutrients in all days during crop growth period followed by soil test based NPK, 100% RDF + FYM + Biofertilizer Consortium, 75% STB NPK + FYM, 100% RDF + FYM, 75% RDF+ FYM + Biofertilizer Consortium, 100% RDF, 75% RDF + FYM and 75% RDF. Available nitrogen content in soil during crop growing season was decreased up to 60 DAS and increased slightly at after harvest soil samples. The range of available N after harvest of crop was from 130 to 221 kg ha^{-1}. After harvest of crop 33.3% decline in available was observed under 75% RDF treatment and increase of 13% was observed in 75% STB NPK + FYM + Biofertilizer Consortium. Available phosphorus content in soil was recorded in the range of 24.7 to 38.6 kg ha^{-1}. P content in soil was declined in all the treatments upto 45 DAS then increased at 60 DAS and after harvest soil samples. When compared with initial P status 100% RDF, 75% RDF and 75% RDF + FYM treatments showed decline of 1.3, 1.9 and 0.9 kg ha^{-1}, respectively and all other treatments showed an incline of 3.5, 4.8, 8.7, 8.9, 11.0 and 12.0 kg ha^{-1} under 75%

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RDF+FYM+ Biofertilizer consortium, 100% RDF+FYM, 75% STB+FYM, 100% RDF+FYM +Biofertilizer consortium, ST based NPK and 75% STB+FYM+ Biofertilizer consortium, respectively. The data at different stages of crop revealed that available potassium declined from 15 DAS to 60 DAS, and then it has increased slightly in after harvest soil samples. At harvest available potassium content in soil varied from 319 kg ha^{-1} to 393 kg ha^{-1}. Further observation of data revealed that higher available potassium was recorded with the integrated application of 75% STB NPK+ FYM + Biofertilizer consortium (393 kg ha^{-1}) which was on par with Soil Test Based NPK which recorded available potassium (387 kg ha^{-1}), 100 % RDF + FYM + Biofertilizer consortium (380 kg ha^{-1}) and 75% STB NPK + FYM (373 kg ha^{-1}). The lower available potassium of 319 kg ha^{-1} was recorded under the treatment 75 % RDF. Sulphur has not been applied as straight fertilizer but along with phosphatic fertilizer different grades of sulphur has also applied to the treatments. At harvest, higher available sulphur was recorded with the integrated application of 75% STB NPK + FYM + Biofertilizer consortium (40.0 kg ha^{-1}) which was on par with Soil Test Based NPK which recorded available sulphur of 38.6 kg ha^{-1}, 100 % RDF + FYM + Biofertilizer consortium (37.8 kg ha^{-1}) and 75% STB NPK + FYM (35.5 kg ha^{-1}). Ammonical nitrogen content in the soil was dominant in soil than nitrate nitrogen content.

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