Annals of Plant and Soil Research 24(1): 16-22 (2022)
https://doi.org/10.47815/apsr.2022.10117

Productivity, nutrient uptake and quality of lentil (*Lens culinaris*) and soil fertility as influenced by organic manures and fertilizers

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Received: September 2021; Revised accepted: October, 2021

ABSTRACT

A field experiment was conducted during the rabi season of 2015-16 and 2016-17 at Panwari village of Agra district, (Uttar Pradesh) to study the effect of organic manures and inorganic fertilizers on yield, uptake of nutrients and quality of lentil (Lens culinaris Medikus). Treatments consisting four levels of organic manures and three levels of inorganic fertilizers were evaluated in factorial randomized block design with three replications. Results revealed that application of 2.5t FYM + 1.25 t vermicompost ha^{-1} resulted in significantly maximum value of plant height (51.2cm), branches/plant (7.4) and pods/plant (116.3) as compared to application of 5t FYM and 2.5t vermicompost ha^{-1} alone and control. Similarly, application of 100% RDF also produced significantly taller plants (50.6cm) and maximum branches/plant (7.6),pods/plant (116.2), grain (1.65t ha^{-1} and straw (2.01t ha^{-1}) yields. The increases in grain and straw yield were 33.0 and 28.0%, respectively due to 100% RDF over control. The significantly highest yield of grain (1.75 t ha^{-1}) and straw (2.12t ha^{-1}) were recorded with combined application of 2.5t FYM + 1.25t vermicompost ha^{-1} than those of 5t FYM and 2.5t vermicompost ha^{-1} alone and control. The increases in grain and straw yield due to 2.5t FYM + 1.25t vermicompost ha^{-1} were 53.5 and 50.3% over control, respectively. The interaction effect of 2.5t FYM + 1.25t vermicompost ha^{-1} and 100% RDF recorded maximum yield of grain (1.95t ha^{-1}) and straw (2.31t ha^{-1}) than other treatment combinations. Combined application of FYM (2.5t ha^{-1}) and vermicompost (1.25t ha^{-1}) recorded significantly highest protein content in grain and straw of lentil. The uptake of nutrients (N, P, K and S) and status of these nutrients in post harvest soil were recorded maximum with 2.5t FYM + 1.25t vermicompost ha^{-1}. Application of 100% RDF also resulted in significantly higher values of protein content, uptake of nutrients and status of available nutrients in post harvest soil than that of 50% RDF.

Keywords: Fertilizers, FYM, lentil, nutrient uptake, organic manure, quality, yield

INTRODUCTION

Lentil (*Lens culinaris Medikus*) is one of the important pulse crop in India. It is used as rich source of protein in vegetarian diet. Lentil helps in maintain soil fertility and symbiotically fixes atmospheric nitrogen in soil.The low productivity of the lentil crop is primarily attributed to low organic matter in soil due to imbalanced and less use of major nutrients. This situation is particularly worsened by continuous cultivation of crops with imbalanced nutrient application. Optimum nutrition is required for getting maximum crop yield and quality. Chemical fertilizers are the main source of nutrients to the crop. Organic manures are good complimentary sources of nutrients and improve the efficiency of the applied mineral nutrients, on one hand, and improve physical and biochemical properties on the other hand. Organic manures such as FYM and vermicompost invariably contain all essential plant nutrients which are released in to the soil solution upon their decomposition by microorganisms. A judicious and combined use of organic and inorganic source of plant nutrients is essential to maintain soil health and to augment the efficiency of nutrients (Saket *et al.* 2015). Additionally, such integration of organic manures and inorganic fertilizers plays an important role in economizing the use of fertilizers under increasing cost, which is restricting their use to an optimum level. Information on the effect of integrated use of organic and inorganic nutrients on lentil crop under Agra condition is not available. Hence, present investigation was carried out to study the effect of organic manures and fertilizer levels on yield, quality and uptake of nutrients in lentil.

MATERIALS AND METHODS

The field experiment was conducted for two consecutive years at farmer field, Panwari villege, Agra (U.P.) during rabi season of 2015-16 and 2016-17. The soil was sandy loam in texture with alkaline reaction (pH 7.9), organic

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carbon 3.1 g kg^{-1}, available N 152 kg ha^{-1}, P 8.8 kg ha^{-1} and K 105 kg ha^{-1}. The experiment was conducted in a factorial randomized block design with three replications. The treatments consisted of four levels of organic manures, viz control, 5 t FYM ha^{-1}, 2.5 t vermicompost ha^{-1} and 2.5 t FYM + 1.25 t vermicompost ha^{-1} and three fertility levels, viz control, 50% recommended dose of fertilizers (10, 30 and 20 kg N, P_2O_5 and K_2O ha^{-1}) and 100% RDF (20, 60 and 40 kg N, P_2O_5 and K_2O ha^{-1}). FYM (0.52% N, 0.30% P and 0.48% K), vermicompost (1.45% N, 0.55% P and 0.67% K) as well as required quantity of N, P and K in the form of urea, single superphosphate and muriate of potash, respectively were applied as per treatments at the time of sowing. Lentil variety T-36 was sown during the last week of November in both the years. Rest of the management practices were in accordance with the recommended package of practices for the crop. Grain and straw yields were recorded at harvest. Plant samples (grain + straw) were dried, ground and digested in di acid mixture (HNO_3 $HClO_4$, 10:4 by volume) and the digest was analysed for P by vanadomolybdate yellow colour method, K by flame photometer and S by tutbidimetric method (Chesnin and Yien, 1951). Nitrogen content in grain and straw was determined by modified Kjeldahl method (Jackson, 1973). Nitrogen value thus obtained was multiplied with a factor of 6.25 to obtain the protein content. The soil samples collected after harvest of crop were analysed for pH by pH meter, organic carbon by Walkley and Black method, available N by alkaline $KMnO_4$ (Subbiah and Asija 1956) available P by Olsen method (Olsen *et al.* 1954), available K by extraction with in NH_4OAc solution at pH 7 (Jackson 1973) and S by Chesnin and Yien (1951). The data obtained during investigation were compiled and the pooled data of two years were analysed for its significance (P=0.05) by statistical procedure as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth and yield attributes

Almost all the levels of organic manures either alone or in combination significantly improved the plant height, branches / plant and pods / plant over the control (Table 1). Application of 2.5t FYM + 1.25t vermicompost ha^{-1} produceded significantly taller plants over control. However, the plant height of lentil crop with 5t FYM ha^{-1} and 2.5t vermicompost ha^{-1} was similar. On the other hand, lower plant height was recorded in the control. The effect of combined use of FYM and vermicompost was more pronounced on plant growth owing to continuous availability of nutrients to lentil plants because of their slow release of nutrients from both the organic manures during the crop season. Similar results were reported by Singh *et al.* (2013). The plant height increased markedly with application of different fertilizer levels and maximum plant height (50.6 cm) was recorded with 100% RDF and minimum in control (37.0 cm). This increase in plant height might be due to greater uptake of nutrients which helps in producing more protoplasm and thereby enhancing rapid cell division and cell elongation which was exhibited in form of increased plant height. The higher number of branches/plant was recorded with 2.5t FYM + 1.25t vermicompost ha^{-1} followed by 2.5t vermicompost ha^{-1} and 5t FYM ha^{-1}. The control plots recorded significantly lower number of branches/plant. This increase may be attributed to better nutrition of plants owing to FYM and vermicompost application. The maximum number of branches/plant was recorded with 100% FDF followed by 50% RDF and control. This was on account of the combined unique functions of N, P and K to boost up plant growth with increased photosynthesis. Similar results were reported by Prajapati *et al.* (2020). The pods/plant was maximum with combined use of FYM (2.5t ha^{-1}) + vermicompost (1.25t ha^{-1}) followed by application of 2.5t vermicompost ha^{-1} and 5t FYM ha^{-1} (Table 1). This improvement in pods/plant may be attributed to higher dry matter production with organic manures which was then reflected in yield attributes (Singh *et al.* 2013). Application of fertility levels increased pods/plant significantly which further increased successively with increasing level of NPK fertilizer up to 100% RDF. This may be owing to increased growth and biomass production as a result of increased supply of NPK.Organic manures did not influence the test weight significantly being a varietal character is less sensitive to management levels. Test weight was not affected with increasing levels of fertilizers (Bhadoria, 2018).

Table 1: Effect of organic manures and fertility levels on yield and quality of lentil (mean of 2 year)

Treatment	Plant height (cm)	Branches /plant	Pods/ Plant	Test weight (g)	Yield (t ha^{-1})		Protein in grain (%)	Protein yield (kg ha^{-1})
					Grain	Straw		
Organic manures (t ha^{-1})								
Control	37.2	5.2	90.5	23.5	1.14	1.41	22.2	253.0
5 t FYM ha^{-1}	44.4	6.7	105.0	24.4	1.37	1.70	22.8	312.3
2.5t Vermicompost ha^{-1}	45.8	6.9	108.0	24.6	1.58	1.93	23.0	363.4
2.5 t FYM + 1.25 t VC. ha^{-1}	51.2	7.4	116.3	24.7	1.75	2.12	23.4	409.5
CD (P=0.05)	5.0	1.1	8.2	NS	0.14	0.18	1.1	12.3
Fertility level (kg ha^{-1})								
Control	37.0	5.1	90.0	23.6	1.24	1.57	22.5	279.0
50% RDF	46.4	6.8	108.5	24.6	1.50	1.82	22.9	343.5
100% RDF	50.6	7.8	116.2	24.7	1.65	2.01	23.2	382.5
CD (P=0.05)	4.0	0.90	7.2	NS	0.12	0.15	1.0	10.6

Yield

The data (Table 1) indicated that grain and straw yield of lentil increased significantly with organic manures over control. The maximum grain (1.75t ha^{-1}) and straw (2.12t ha^{-1}) yields were recorded with combined use of 2.5 FYM + 1.25t vermicompost ha^{-1} and minimum (1.14 and 1.41t ha^{-1}) in control. The increases in grain and straw yield due to 2.5t FYM + 1.25t vermicompost ha^{-1} were 53.5 and 50.3%, respectively over control. This might be attributed to rapid mineralization of nitrogen and steady supply of N from FYM and vermicompost which might have met the N requirement of crop at critical stages. Application of vermicompost proved superior in improving, the yield of grain and straw of lentil as compared to FYM. The beneficial effect of organic manures on yield of crops was also reported by Saket *et al.* (2014). The minimum yields of grain and straw were recorded in control plots (no fertilizer) which may be attributed to low fertility status of soil. The 100% RDF resulted in significantly higher grain and straw yield followed by 50% RDF. Increases in grain yield with 50% and 100% RDF were 21.0 and 33.0 % respectively over control. The corresponding increases in straw yield with 50% and 100% RDF were 15.9 and 28.0 per cent. The higher productivity of the crop may be due to higher yield attributes under these treatments. These results corroborate with those of Prajapati *et al.* (2020).The interaction between organic manures and soil fertility levels was significant with respect to yield of lentil (Table 2).

Table 2: Interactive effect of organic manures and fertility levels on yield of lentil (mean of 2 years)

Organic manures (t ha^{-1})	Fertility level (kg ha^{-1})		
	Control	50% RDF	100% RDF
Grain yield (t ha^{-1})			
Control	0.95	1.15	1.32
5 t FYM ha^{-1}	1.11	1.40	1.56
2.5t Vermicompost ha^{-1}	1.36	1.64	1.80
2.5 t FYM + 1.25 t VC ha^{-1}	1.52	1.80	1.95
CD (P=0.05)		0.27	
Straw yield (t ha^{-1})			
Control	1.18	1.44	1.63
50% RDF	1.49	1.70	1.95
100% RDF	1.70	1.95	2.17
2.5Tfym + 1.25t VC ha^{-1}	1.90	2.15	2.31
CD (P=0.05)		0.34	

Treatment combination of 2.5t FYM + 1.25t vermi compost ha^{-1} and 100% RDF, being at par with 2.5t FYM + 1.25t vermicompost ha^{-1} + 50% RDF proved significantly superior to other combinations in respect of grain and straw yield. The maximum grain (1.95 t ha^{-1}) and straw (2.31 t ha^{-1}) production was recorded with 2.5t FYM + 1.25t vermicompost ha^{-1} and 100% RDF. This

increase in yield due to this treatment might be owing to beneficial effects of combined application of organic manures and fertilizers. These results are in conformity with the findings of Saket *et al.* (2015) and Kumar *et al.* (2018).

Quality

Protein content in lentil grain was significantly influenced by various levels of organic manures. Application of 2.5t FYM + 1.25t vermicompost ha^{-1} resulted in significantly higher protein content in lentil grain (23.4 %) followed by 2.5t vermicompost ha^{-1} and 5t FYM ha^{-1}. This may be due to accumulation of more N with these treatments and ultimately showing more protein content in grain (Deshmukh and Jain 2014).The lowest amount of protein was noted in control (no organic manures) which may be attributed to absorption of low amount of N from the soil. Application of organic manures recorded significantly higher protein yield over control owing to higher yield of grain. Lowest protein yield was recorded in control due to low yield of grain. This increase in protein content may be attributed to increased grain yield and protein content in grain (Prajapati *et al.* 2020). There was a significant increase in protein content of lentil grain due to graded levels of NPK fertilizers. The maximum amount of Protein (23.2%) was recorded with 100% RDF, whereas the minimum (22.5%) was recorded in control. Application of 50% RDF also improved the protein content significantly over control. Soil fertility levels produced beneficial effect on protein production in comparison to control. The maximum protein yield (382.5kg ha^{-1}) was recorded with 2.5t FYM + 1.25t vermicompost ha^{-1} indicating the beneficial effect on nitrogen absorption and yield of crop.

Nutrient uptake

Significantly higher uptake of nitrogen was recorded with the application of 2.5 t FYM + 1.25 vermi compost ha^{-1} followed by 2.5 t vermicompost ha^{-1} and 5 t FYM ha^{-1} alone treatments (Table 3). The uptake of N by lentil crop was relative higher in vermi compost treated plots than in FYM treated plots owing to better availability of N by plants. The increase in N uptake by lentil grain and straw might be attributed to enhanced activity of nitrogenous and nitrate reductase enzyme in soil. Similar results were reported by Saket *et al.* (2015) in lentil. The increasing fertility levels up to 100% RDF resulted in higher uptake of N by lentil grain (61.3 kg ha^{-1}) and straw (24.1 kg ha^{-1}) over control. Higher values of N uptake with higher soil fertility level are apparently the result of favourable effect of this treatment on N absorption coupled with greater yields (Bhadoria 2018).The phosphorus uptake by grain and straw of lentil increased with addition of organic manures whereas lowest P uptake was recorded in control. Among organic manures, combined use of 2.5t FYM + 1.25 t vermicompost was more effective in improving the utilization P by crop over FYM and vermicompost alone treatments. This increase in P uptake may be attributed to its solubilization caused by the organic acids produced during the process of decomposition of organic manures. Saket *et al.* (2015) also recorded higher P uptake by lentil crop with the addition of organic manures. The uptake of P by lentil crop increased significantly with the application of fertilizers and maximum values of P uptake by grain (4.9 kg ha^{-1}) and straw (3.6 kg ha^{-1}) were recorded with 100% RDF. This may due to the fact that P fertilization results in a better growth and deeper ramification of roots causing higher P uptake (Singh and Singh, 2014). The significantly higher uptake of K by lentil grain and straw was recorded in plots treated with 2.5t FYM + 1.25 t vermicompost ha^{-1}. Application of 5t FYM ha^{-1} and 2.5t vermicompost ha^{-1} alone treatments also improved the utilization of K by lentil crop over control. The increased uptake of K by lentil crop may be ascribed to release of K from the K bearing minerals by complexing agents and organic acids produced during the decomposed of organic manures (Saket *et al.* 2015). Application of fertilizer to the soil proved beneficial for K uptake by lentil grain and straw over control. The 100% RDF removed maximum amounts of K from the soil by grain (12.7kg ha^{-1}) and straw (24.1 kg ha^{-1}). Moreover, higher amount of K was removed in straw than grain; it was merely because of higher content of K in straw of the crop.The uptake of S by grain and straw of lentil increased significantly with the addition of organic manures and maximum S uptake by grain (5.9 kg ha^{-1}) and straw (4.9 kg ha^{-1}) was recorded with 2.5t FYM + 1.25 t vermicompost ha^{-1}, This increase in S uptake by

the crop may be attributed to increased yield of lentil due to addition of organic manures. The S uptake by lentil grain and straw improved with the addition of fertilizer The S uptake in grain increased from 3.8 kg ha^{-1} at control to 5.4 kg ha^{-1} with 100% RDF. The corresponding increase in straw was from 3.1 to 4.4 kg ha^{-1}.

Table 3: Effect of organic manures and fertility level on uptake of nutrients (kg ha^{-1}) by lentil (mean of 2 years)

Treatment	Nitrogen		Phosphorus		Potassium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Organic manures (t ha^{-1})								
Control	40.5	15.5	2.8	2.1	8.0	15.5	3.4	2.7
5 t FYM ha^{-1}	50.1	19.3	3.7	2.7	10.0	19.2	4.3	3.6
2.5 Vermicompost ha^{-1}	58.3	23.0	4.4	3.1	11.7	22.2	5.0	4.2
2.5 t FYM + 1.25 t VC ha^{-1}	65.2	25.8	5.2	3.8	13.3	24.5	5.9	4.9
CD (P=0.05)	6.6	2.7	0.46	0.40	1.05	2.17	0.34	0.37
Fertility level (kg ha^{-1})								
Control	44.6	17.5	2.9	2.2	8.4	17.1	3.8	3.1
50% RDF	58.1	21.1	4.4	2.9	11.7	20.7	5.1	3.8
100% RDF	61.3	24.1	4.9	3.6	12.7	24.1	5.4	4.4
CD (P=0.05)	5.7	2.5	0.40	0.35	0.91	1.89	0.30	0.32

Soil fertility

The pH of soil decreased significantly with graded levels of organic manures. The maximum pH was recorded in control and the minimum pH was recorded due to application of organic manures. The gradual decrease in soil pH with the application of organic manures might be due to the decomposition of organic manures and release of organic and inorganic acids such as carbonic, citric and melic acids as well as H^+ produced from mineralization of N in the organic matter.The organic carbon content in post harvest soil improved with addition of organic manures over control. The maximum content (3.15g kg^{-1}) was recorded with 2.5t FYM + 1.25t vermicompost ha^{-1}. The slow decomposition rate of added organic manures with high organic load contributed to build up organic carbon in post harvest soil. Similar findings were also reported by Kumar *et al.* (2018). There was a significant increase in organic carbon content of soil due to graded levels of soil fertility. The maximum organic carbon content was recorded with the application of 100% RDF whereas the minimum was recorded in control. Increase in organic carbon content in post harvest soil due to increase in fertility levels might be attributed to higher roots biomass production. The status of available nitrogen in soil at harvest significantly increased due to application of organic manures (Table 4).

Table 4: Effect of organic manures and soil fertility on status of available nutrients in post harvest soil (mean of 2 years)

Treatments	pH	Org. C (g kg^{-1})	Available nutrients (kg ha^{-1})			
			N	P	K	S
Organic manures (t ha^{-1})						
Control	8.0	3.00	135	8.0	86	12.4
5 t FYM ha^{-1}	7.9	3.06	145	9.5	95	14.0
2.5t Vermicompost ha^{-1}	7.9	3.12	150	10.0	112	14.2
2.5 t FYM + 1.25 t VC. ha^{-1}	7.8	3.15	160	10.8	126	15.0
CD (P=0.05)	0.11	0.08	4.5	0.71	9.8	0.51
Fertility level (kg ha^{-1})						
Control	7.9	3.05	140	8.4	85	13.2
50% RDF	8.0	3.08	148	9.7	107	14.0
100% RDF	8.1	3.11	155	10.6	118	14.6
CD (P=0.05)	0.09	0.05	3.9	0.62	8.4	0.44

The maximum available nitrogen content in soil was recorded with 2.5 t FYM + 1.25t whereas the minimum was recorded in control (13.5 kg ha^{-1}). Sole application of 5t FYM and 2.5t vermicompost ha^{-1} showed significant increase in available N content over control. The increase in available N content as a result of organic manures may be ascribed to its organic matter content. Most of the nitrogen present in soil is bound in organic form, which upon decomposition released in soil over a period of time. Kumar *et al.* (2018) also reported an increase in available N in post harvest soil with the addition of organic manures.There was a significant build up of available nitrogen in post harvest soil with the application of inorganic fertilizers which was significantly higher than control. The highest available nitrogen (155 kg ha^{-1}) was recorded in 100% RDF treatment. Application of 50% RDF also improved the status of available N in soil as compared to control. The lowest value of available N was recorded in control. The increase in available N with increasing levels of soil fertility may be attributed to addition of N to soil. Similar results were reported by Kumar *et al.* (2018). .

Application of organic manures increased the soil available P significantly over control and higher amount of available P was recorded with the application of 2.5t FYM + 1.25t vermicompost ha^{-1} followed by 2.5t vermi compost ha^{-1} and 5t FYM ha^{-1}. The control plots recorded significantly low content of available P. The increase in available P might be due to the organic acids which were released during microbial decomposition of organic matter which helped in the solubility of native P as a result of which the availability of P content increased. Chaudhary *et al.* (2004) also reported an increase in available P in post harvest soil with the application of organic manures. The available P in soil was significantly improved due to addition of fertilizers over control. Improvement in P status in soil was noted due to increase in rate of NPK from 50% to 100% RDF due to addition of phosphorus through the application of chemical fertilizers. Available K content in post harvest soil increased significantly due to addition of organic manures over control. The maximum available K content in soil was recorded with the application of 2.5t FYM + 1.25t vermicompost ha^{-1} whereas the minimum in control (86 kg ha^{-1}). The organic manures used in the present study contained K which might have increased the available soil K. The straw and root residue of the crop left over in the field also significantly contributes to soil available K, this might also be a reason for its increase in the available soil K at harvest. A perusal of data (Table 4) revealed a decline in control as compared to the initial level (105 kg ha^{-1}) of available K which indicates a mining of available K. Addition of fertility levels (50 and 100% RDF) improved the status of available K in post harvest soil and maximum available K status (118 kg ha^{-1}) was found in the treatment having 100% RDF followed by 50% RDF. This increase in available K may be attributed to direct addition to the available K pools of soil (Kumar *et al.* 2018). Application of organic manures increased available sulphur in post harvest soil over control. Increase in available sulphur content might be attributed to application of organic manures rich in organic sulphur. Available sulphur content in post harvest soil increased markedly with graded levels of soil fertility over control. The maximum available S content of 14.6 kg ha^{-1} was recorded in 100% RDF while the minimum of 13.2 kg ha^{-1} being in control. This increase may be attributed to higher root activity leading to production of root exudates which might increase available S content in soil (Chaudhary *et al.* 2004).

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