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Perennial fodder crops as a tool for carbon dioxide assimilation in winter by application of best combination of fertilizer doses

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Abstract

For increasing carbon stock in soil cropping of fodders with best fertilizer combination doses is necessary. As based on various research papers it is obvious that fodder crops have great opportunity to fix and store carbon in the soil. Carbon assimilation in fodder crops viz; oat (JHO 20-10), lathyrus (Ratan), berseem (BB-3) & makhan grass (Hybrid Variety) cultivated by farmers of M.P as influenced by four fertilizer treatments viz:100% RDF through vermi-compost (10 tonnes/ha), 100% RDF (NPK 50:50:40), 50% RDF through Vermi-compost + 50% RDF(NPK) through inorganic fertilizers (5tonnes/ha+NPK 25:25:20) & control fodders (no fertilizer) was assesed during 2017-18 & 2018-19 in *Rabi* season at the research farm of CoA, Gwalior. The field had homogenous fertility and uniform textural make up. The soil properties, soil organic carbon content, plant organic carbon, fodder yield, plant growth parameters, fresh and dry weight of fodders were studied. The results of the study revealed that growing of oat in comparison to lathyrus, berseem and makhan grass as a fodder crop in dry areas will play a vital role to some extent as it has a capacity to assimilate higher carbon from the atmosphere and so help in mitigating the global warming. Growing fodder crops will store carbon and by planting fodders will also provide a good quality green fodder for the animals reared by the farmers. Carbon assimilation in fodder crops revealed that oat crop when applied with 50% RDF through Vermi-compost + 50% RDF through (5 tonnes/ha+ N P K 25:25:20) was best among other fodder crops for higher carbon storage in the soil followed by 100% RDF (NPK 50:50:40) & 100 % vermi-compost (10 t/ha) application.

Therefore, farmers may be advised to select oat crop, among other fodders for higher carbon assimilation. Consequently, higher carbon sequestration will be assured in successive years. The next better fertilizer dose combination was 100% RDF (NPK 50:50:40) followed by 100 % vermi compost (10 t/ha) for oat crop.

Keywords: Fodder crops, Fertilizer treatment, Carbon assimilation, fertility level

Introduction

Carbon sequestration is the process of removal of carbon-dioxide from atmosphere in to green plants where it can be stored indefinitely. This sequestration program can play a vital role since carbon capture and storage helps the world in stabilizing and consequently diminishing the greenhouse gas emission (Watson et al., 2000).Carbon sequestration has to be quantified to improve the storage ability of all potential sinks and expand the number and type of sinks in which carbon storage is possible by means of various practices and technologies. Soil carbon sequestration is globally important and has great benefit to agriculture. Due to industrialization and reduction of carbon sinks during the past decades the carbon-dioxide concentration in the atmosphere has rapidly increased. Different kinds of strategies have been suggested for increasing carbon sequestration which includes manuring, nutrient management, agroforestry practices and cultivation of fodder crops on uncultivable & fallow lands, water conservation and harvesting. Sustaining soil health through inclusion of manure in the fertilization schedule and applications plays a vital role since it improves the organic carbon content and available N, P, K and S in soil (Tiwari *et al*., 2002). For improving soil physical properties, there is a need to add various organic manures along with NPK in the fields as organic matter increases soil organic carbon compared to application of NPK through inorganic fertilizers (Bhattacharya *et al*., 2008). Chemical fertilizers must be integrated with organic manures such as FYM , compost, crop residues and green manures which are eco-friendly to achieve sustainable productivity with minimum deleterious effects of chemical fertilizers on soil, health environment animals and humans. In the present time more preference is given for organically grown produce as they are free of toxic residues and also better for soil health and environment. Animal manure is a good source of organic fertilizer that helps to improve chemical, physical and biological properties of soil and as a source of energy for the soil ecosystem. Promoting soil carbon sequestration is an effective way to reduce atmospheric CO_2 and thereby improve soil quality. Quantification of soil organic carbon in relation to various crop management practices is of importance in identifying sustainable systems for carbon sequestration in soils.

Significant work has been carried out with respect to carbon sequestration potential in fodder crops. The potential of soil carbon sequestration in India was estimated at 7 to 10 Tg C/yr for restoration of degraded soils and ecosystems, 5 to 7 Tg C/yr for erosion control, 6 to 10 Tg C/yr for adoption of recommended practices on agricultural soils (Lal, 2004). An integrated farming practice can decrease carbon-dioxide emission from soil into the atmosphere and enhance the soil fertility along with productivity. Thus soil carbon sequestration is globally significant for agriculture. Due to industrialization and reduction of carbon pools in past few decades the concentration of carbon-dioxide in the atmosphere has rapidly increased. Conversion of arable agriculture to perennial plants can also contribute to sequestration of carbon. Hence, sequestration of the excess carbon from the atmosphere necessitates a sustainable approach to capture excess carbon-dioxide in an integrated manner that satisfy biogeochemical and ecosystem norms. By means of various practices and technologies, sequestration needs to be quantified to enhance the storage ability of all potential sinks and expand the number and type of sinks in which carbon storage is possible.

The fodder crops along with carbon assimilation and ultimately sequestration over a long run will improve the soil organic carbon storage. So a study of five years is undertaken to find the carbon uptake by the commonly grown winter fodder crops. This study will continue further for three years to calculate carbon sequestered by these fodder crops. Then only recommendation to farmers can be provided based on the research findings. The study presented here is the outcome of two years of research on this aspect.

Materials & Methods

Experimental site: The present experiment was carried out, during *rabi* season of 2017-18 and 2018-19 at the research farm, College of Agriculture, Gwalior. The research farm is situated at the latitude of 26.2133^0 North and longitude 78.1828° East with an altitude of 211.52 meters above mean sea level. The field having homogenous fertility and uniform textural make up was selected for the field experimentation.

Climate and weather conditions: The region comes under semi-arid and sub-tropical climate with extreme weather condition having hot and dry summer and cold winter. Generally, monsoon sets in the last week of June. Annual rainfall ranges from 700 to 800 mm, most of which falls during last week of June to the middle of September. Winter rains are occasional and uncertain. The maximum temperature goes up to 47^oC during summer and minimum as low as $2.8^o C$ during winter. In some years frost is also seen between last week of December to the first week of February in this region. The average relative humidity ranged between 15.5 and 96.3 percent during the cropping season.

Soil characteristics of experimental site: The soil of the experimental field was alluvial, sandy clay loam in texture. Representative soil samples of surface (0-15 cm depth) were collected from each plot before sowing with the help of soil auger for determination of physico-chemical properties of soil. Soil of the experimental field was sufficient in potash content, but low in organic carbon, available nitrogen and medium in available phosphorus contents.

Crop & Fertilizer management: The land was ploughed twice by a tractor with chisel plough followed by harrowing. The field was brought to fine tilth, levelled with a wooden plank and laid out in to the plots as per the lay out plan. The experimental crops taken were makhan grass (Hyb), lathyrus (Ratan), berseem (BB-3) and oat Jho (20-10) as these crops are easy to grow in Gwalior agro-climatic zone. The seed rate of 25 kg per ha was followed for all the fodders. The plant to plant distance within the row was 20 cm and row to row spacing was 25cm. The four different fertility levels were taken as treatments viz; 100% vermi-compost (10 tonnes/ha), 100% RDF (NPK 50:50:40), 50% RDF through Vermi-compost + 50% RDF fertilizers through NPK (5 tonnes/ha+NPK 25:25:20) and control plots (no fertilizer). The fertilizer was applied in two split doses. Initial dose was applied along with irrigation on 7th day after sowing and second dose was applied at 45 DAS.

Vermi compost was applied as per the recommended dose of 10 tonnes/ha before sowing. Irrigation was carried out immediately after sowing (0th day), on 3rd day and thereafter once in 7 days for all fodder crops. Harvesting was carried out at 90 DAS. The annual crops were cut close to the ground level. Green fodder yield was recorded from each net plot in one square meter area and expressed in tonnes/ha. Immediately after each cut fresh fodder was weighed. Three cuttings (30, 60 and 90 days after sowing) were taken during the experiment.

Chemical analysis and growth parameters.

Five fodder samples, from each treatment plot were harvested at random just above the ground level at 30th day, 60th day and 90th day and at final harvesting stage at (120 DAS). The samples were shade dried and kept in oven at 60 - 70°C till constant weight was obtained. The carbon uptake (assimilation) by the plant was calculated using the formula Carbon uptake (Assimilation) = Biomass x Carbon (%) by Negi *et al.*, 2003. Carbon % was calculated by subtracting ash weight (gm) of the full plant from its dry weight (gm) and then converted in to per cent. The growth and yield parameters were observed at equal interval of 30, 60 and 90 days after sowing.

Statistical Analysis and Interpretation of Data

The data collected on different parameters during the course of investigations were subjected to‘t’ test to find out the significant difference between treatments at different fertility levels. In total 16 treatment combinations with 4 replications were designed for study. One way Analysis of Variance (ANOVA) of SPSS 13.0 was performed to find the significant difference in fertility level and fodder crops by using split plot design. Interpretation of data was done as per the procedure described by Gomez and Gomez (1984).

Results & Discussion

Effect of fertility levels on growth parameters of fodders

The number of plants per plot at harvest were non-significantly affected (Table1) however, higher number of plants were in berseem (16) and lowest in lathyrus (10). Number of plants ranged between 13.67 to 14.67 in makhan grass, 6.33 to 9.33 in lathyrus, 13.33 to 16.33 in berseem and 11 to 13.58 in oat. These findings are supported by Srinevasan (1992). In respect of number of branches at harvest (Table2) were significantly higher in makhan grass followed by berseem and lathyrus. Number of branches/plant had non-significantly difference except, lathyrus showed significantly higher no. of branches when applied with 100% RDF through NPK and 50% RDF through NPK 25:25:20+50% Vermi-compost.

Height of plants significantly increased at all crop growth stages and maximum height was recorded in oat 59.17, 72.67 & 79.42cm at 30,60, 90 DAS respectively and minimum height was in makhan grass at all crop growth stages. Increase in height of plants was found significant when applied with 50% Vermi compost +50% RDF through NPK25:25:20 (VC 5t/ha+ NPK 25:25:20) in all the crops at all crop growth stages. (Table3)

The results showed that the application of RDF through NPK and Vermi compost or in combination increased the carbon uptake at each crop growth stages significantly over the control. Maximum carbon in each crop was recorded by application of 50% RDF through NPK 25:25:20 +50% Vermi- compost. Similar, results were also observed by Thennarasu*et. Al* (2016). All the above results are supported by Minhas and Sord (1994) who observed increase in yields of maize with application of FYM at 20 t /ha. Ghosh *et.al.* (2004) also reported that organic manure along with NPK significantly increased the yield of sorghum. These finding are supported by Balyan et al (2006) found that application of FYM@ 10 t/ ha along with fertilizers increased plant height to 10.26 % as compared to application of 100% recommended dose of fertilizers which increased the plant height by 8.17% .Kannan *et al* (2006) also revealed the substitution of 100% N through FYM. No. of branches / plant was significantly higher over the control at all fertility levels in all the fodder crops. However, maximum no. of branches were when 50% RDF through vermi compost + 50% RDF through NPK2 5:25:20 (VC 5t/ha+ NPK 25:25:20) was applied for all crops. These findings are also supported by Shah et al .(2009) who found that urea and FYM manure significantly showed better growth and development of maize plants as N was available in proper proportion and at proper time. (Table 1, Table 2, Table 3)

Effect of fertility levels on dry weight of fodder crops.

Dry weight (gm/plant) of all the fodder crops at all crop growth stages was more when it was fertilized with 50% RDF through vermi- compost + 50% RDF through NPK2 5:25:20 (VC 5t/ha+ NPK 25:25:20). In general the dry weight per plant was minimum in control at all crop growth stages. It was observed that dry weight improved with the advancement of age. The maximum dry weight (66.00 g/plant) was observed in oat and minimum (20.67g/plant) in makhan grass and all crop growth stages.(Table4)

These results are supported by the study done by Sharma et al (2012) who observed that dry matter yield significantly increased in Hybrid Napier adding 20 t /ha of FYM and 80 kg / ha N compared to other treatments. Another study done by Salam and Salam in 2012 also supports present study that dry matter yield increased from 13.5 t/ha to 21.1 t/ha because of application of potassium fertilizer along with FYM (Table 4)

Effect of fertility levels on green fodder yield

The result showed that the application of RDF of NPK as well as vermi- compost alone or in combination increased the production of fodder at each crop growth stages over the control. Maximum fodder yield was recorded at 50% RDF through vermin- compost + 50% RDF through NPK 25:25:20 (VC 5t/ha+ NPK 25:25:20) in all the crops. Minimum fodder yield was observed in lathyrus under all fertility levels. The green fodder yield was maximum at all crop growth stages in oat 17.83 q/ha and varied significantly. (Table 5a, b, c)

These findings are supported by the study of Ghosh et al. (2004). They found that the use of organic manure with NPK played a vital role in increasing the yield of sorghum, soybean due to steady supply of essential mineral nutrients. Ashok Kumar (2005) also showed that the application of 10 tonnes / ha FYM with 100% NPK increased grain yield in maize.

Present study results highest grain yield in oat crop (0.59g/plant) is also supported by Amujoyegbe *et. al*. (2007). They concluded that mixture of inorganic and organic fertilizer improved plant height and grain yield for sorghum & maize as compared to inorganic treated plots. This is due to the fact that combination of inorganic and organic are better nutrient source as compared to inorganic fertilisers alone provide early nutrients to the growing crops during early vegetative growth stages, while the organic fertilizers component provided nutrient at later stage of crop development as it takes some time for mineralization.(Table 5a, Table 5b, Table 5c)

Effect of fertility levels on carbon uptake in fodder crops

The results revealed significant difference in carbon uptake at all crop growth stages in fodder crops. Maximum carbon was seen in oat (31.35 %) followed by berseem (17.10 %), lathyrus (12.35 %) & makhan grass (9.82 %) at harvest. Carbon uptake by different fodder crops showed significant variation at different crop growth stages. There was significant increase in carbon uptake up to maturity which was similar to findings of Sivakumar & Meenakshi in 2012. High carbon uptake in oat may be due to high biomass yield as compared to other crops.

All the crops when fertilized with 50% RDF through vermi- compost +50% RDF through NPK 25:25:20 showed more carbon uptake over other fertility levels. In general minimum carbon uptake was observed in control plots.(Table 6a,b,c)

The present finding is supported by Rahman *et al*.(2008) which says that the high organic carbon 52.08-53.8% in maize was due to individual mineral contents in soil and manure and also due to organic matter content of fodder. Another study done by Efthimiadou *et al.* (2010) at also supports the present study as it says that plant organic carbon of fodder maize was higher for treatments which included cow manure. Afzal *et. al*. (2013) said that increase or decrease of organic carbon in plant depends mainly on the dry matter production of fodder crop. (Table 6a, Table 6b, Table 6c)

Conclusion

The results of the study derives at a conclusion that growing of oat as a fodder crop in dry areas will play a vital role to some extent as it has a capacity to uptake more carbon from the atmosphere and so help in mitigating the global warming. Along with carbon storage it will provide a good quality green fodder for animals. The best fertility level was found to be 50% RDF through Vermi- compost + 50% RDF through NPK (5 tonnes/ha+ N P K 25:25:20) followed by 100% RDF through (NPK 50:50:40) & 100 % vermi-compost (10 t/ha).

So as a conclusive remark it can be said based on two years data that oat with application of 50% RDF through Vermi compost + 50% RDF through NPK (5 tonnes/ha+ N P K 25:25:20) can be selected among other fodders in the Gwalior region for higher carbon uptake and as a consequence it will be helpful in carbon sequestration when grown for more years. The next better fertility level was 100% RDF through (NPK 50:50:40) followed by 100 % vermi- compost (10 t/ha) for oat crop

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Table 1- -Effect of fertility levels on number of plants per plot at harvest

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermicompost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	14.67	14.00	14.67	13.67	14.25
Lathyrus (Ratan)	9.00	9.00	9.33	6.33	8.75
Berseem (BB3)	14.67	16.00	16.33	13.33	15.08
Oat (JHO 20-10)	12.67	12.67	14.33	11.00	12.67
F-Mean	12.75	13.33	13.58	11.08	
	(CxF)1		**(CxF)2**		
Sem±	**0.839**		**1.050**		
CD (5%)	**2.449**		**3.360**		

Table 2 -Effect of fertility levels on number of branches at harvest

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermi compost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	151.00	152.00	155.00	147.67	151.42
Lathyrus (Ratan)	73.67	77.33	86.67	71.33	77.25
Berseem (BB3)	120.33	123.00	126.00	116.33	121.42
Oat (JHO 20-10)	46.33	48.33	50.33	45.00	47.50
F-Mean	97.83	100.17	104.50	95.08	
	(CxF)1	**(CxF)2**			
Sem±	**0.771**	**2.091**			
CD (5%)	**2.251**	**7.119**			

Table-3 Effect of different fertility levels on height (cm) of plants at harvest (90 DAS)

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermi compost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	**29.67**	32.33	36.00	26.33	31.08
Lathyrus (Ratan)	41.67	45.00	46.67	38.67	43.00
Berseem (BB3)	66.00	60.00	63.67	60.00	63.17
Oat (JHO 20-10)	70.67	74.67	**76.67**	68.67	72.67
F-Mean	52.00	55.50	58.25	49.17	
	(CxF)1		**(CxF)2**		
Sem±	**1.602**		**2.159**		
CD (5%)	**4.677**		**6.988**		

Table-4 Effect of different fertility levels on dry weight (g/plant) of plants at 90 DAS/harvest.

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermicompost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	18.33	19.00	20.67	17.00	18.75
Lathyrus (Ratan)	21.67	23.67	26.00	19.00	22.58
Berseem (BB3)	33.33	34.33	36.00	34.67	34.58
Oat (JHO 20-10)	63.33	65.00	66.00	62.00	64.08
F-Mean	34.17	35.50	37.17	33.17	
	(CxF)1		**(CxF)2**		
Sem±	**0.531**		**0.619**		
CD (5%)	**1.551**		**1.958**		

Table-5 a Effect of different fertility levels on green fodder yield (q/ha) at 30 DAS.

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermi compost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	5.67	6.67	7.67	4.83	6.21
Lathyrus (Ratan)	4.33	4.83	6.00	**3.33**	4.63
Berseem (BB3)	6.17	6.50	7.17	5.67	6.38
Oat (JHO 20-10)	15.67	17.17	**18.17**	14.33	16.33
F-Mean	7.96	8.79	9.75	7.04	
	(CxF)1		**(CxF)2**		
Sem±	**0.264**		**0.402**		
CD (5%)	**0.769**		**1.321**		

Table-5b Effect of different fertility levels on green fodder yield (q/ha) at 60 DAS.

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermi compost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	7.33	8.00	8.50	6.83	7.67
Lathyrus (Ratan)	4.67	5.00	5.50	**3.83**	4.75
Berseem (BB3)	7.17	7.67	8.50	7.00	7.58
Oat (JHO 20-10)	13.67	14.17	**14.67**	12.83	13.83
F-Mean	8.21	8.71	9.29	7.63	
	(CxF)1		**(CxF)2**		
Sem±	**0.163**		**0.323**		
CD (5%)	**0.476**		**1.083**		

Table-5c Effect of different fertility levels on green fodder yield (q/ha) at 90 DAS

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermi compost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	10.00	11.17	11.67	9.50	10.58
Lathyrus (Ratan)	6.67	6.73	7.73	**6.17**	6.83
Berseem (BB3)	8.80	9.50	10.00	8.33	9.16
Oat (JHO 20-10)	15.83	16.67	**17.83**	15.17	16.38
F-Mean	10.33	11.02	11.81	9.79	
	(CxF)1		**(CxF)2**		
Sem±	**0.237**		**0.404**		
CD (5%)	**0.691**		**1.343**		

Table6a Effect of different fertility levels on carbon uptake (%) in fodder crops at 30 DAS

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermi compost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	**6.49**	7.13	9.03	6.18	7.20
Lathyrus (Ratan)	7.76	7.92	7.92	7.44	7.76
Berseem (BB3)	13.78	14.25	15.68	13.46	14.29
Oat (JHO 20-10)	28.66	29.61	**30.88**	25.65	28.70
F-Mean	14.17	14.73	15.87	13.18	
	(CxF)1		**(CxF)2**		
Sem±	**0.294**		**0.290**		
CD (5%)	**0.859**		**0.884**		

Table 6b Effect of different fertility levels on carbon uptake (%) in fodder crops at 60 DAS

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermi compost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	**5.70**	6.65	9.03	6.97	7.09
Lathyrus (Ratan)	7.60	9.03	9.98	7.76	8.59
Berseem (BB3)	14.25	15.04	16.31	14.25	14.96
Oat (JHO 20-10)	28.34	29.29	**30.93**	26.76	28.58
F-Mean	13.97	15.00	16.31	13.93	
	(CxF)1		**(CxF)2**		
Sem±	**0.207**		**0.244**		
CD (5%)	**0.604**		**0.772**		

Table 6c Effect of different fertility levels on carbon uptake (%) in fodder crops at 90 DAS

Treatment combination	**100% vermi compost (10t/ha)**	**100% RDF through NPK 50:50:40**	**50% RDF through vermi compost+50% RDF through NPK (VC 5t/ha+ NPK 25:25:20)**	**Control**	**C-Mean**
Makhan grass (Hyb)	**8.71**	9.03	9.82	8.08	8.91
Lathyrus (Ratan)	10.29	11.24	12.35	9.03	10.73
Berseem (BB3)	15.83	16.31	17.10	16.47	16.43
Oat (JHO 20-10)	30.08	30.88	**31.35**	29.45	30.44
F-Mean	16.23	16.86	17.65	15.75	
	(CxF)1		**(CxF)2**		
Sem±	**0.252**		**0.294**		
CD (5%)	**0.737**		**0.930**		