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Liming influence on fenugreek productivity including disease incidence and nutritional parameters of plant and soil under Typic Haplustalfs

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Abstract

Field experiments were carried out consecutively three years in acid soils of Ranchi, Jharkhand, India on fenugreek (*Trigonella foenumgraecum*) with various fractions of recommended dose of lime (RDL) ie, 25%, 50%, 75% and 100% and these were compared with control (No lime) and neutral soil conditions too. Results revealed that growth and yield parameters of fenugreek variety AFg-1 positively influenced by applied fractions of RDL. Growth and yield was more pronounced at 100% use of RDL. Per cent yield increase with corresponding fractions of lime was 15.0, 17.5, 18.1 and 37.4, respectively. Seed yield was directly correlated with soil available N, P, K and seed N content, and their corresponding r^2 values were 0.90, 0.97, 0.89 and 0.94, respectively. Impact of lime was wide at early growth stages haulm to seed than later. N, P, K and protein content increased with lime and Fe, Mn and Zn content was lower. P translocated highest from straw to seed followed by K and N. Uptake of all the nutrients was more with lime. Moreover, N, P and K content was many fold lower in acid soil than the origin of variety ie neutral pH, whereas micronutrient content was higher in fenugreek under acid soil than neural. Soil available nutrients were influenced marginally with lime. However, soil EC and pH increased and soil organic carbon (SOC) decreased. Per cent disease index (PDI) was more with liming/soil pH (r^2 = 0.97), soil available Mn (r^2 = -0.94) and leaf Mn content (r^2 = -0.88). Due to high humidity, it was persistently higher at Ranchi than the Ajmer; a place of origin of variety. The combine effect of soil acidity and disease, in reduction of yield was accounted about 50-60% as compared to neutral soil. Hence, liming improved soil properties and fenugreek productivity but adversely affect the SOC and encouraged disease incidence.

Key words : AFg-1, acid soil, growth, liming, nutrient uptake & translocation, powdery mildew, soil available nutrients, yield.

Introduction

Based on the recent estimates, 60 per cent land area on earth occupied by the acid soil. In India, total area under degraded and wastelands is 147.75 M ha and the extent of area under chemical degradation particularly by acidification (pH < 4.5 -5.5) was estimated as 16.03 M ha (ICAR, 2010). According to different possible classes with different stake holders, the extent of this chemically degraded area has been estimated as 10.71 M ha. In the Jharkhand state, soils mainly developed on granite gneiss (32.6%) and granite schists (14.2 %). Soil acidity problem (pH < 5.5) is acute in 4 lakh hectare of cultivated area. Soil acidification takes place by depletion of calcium and magnesium through leaching process and uptake by crops. Low pH and lower levels of organic carbon, K, Ca, Mg and in some places micronutrients also major constraints for growing general crops in these soils. Liming in these soils play a crucial role for enhancing their productivity, however liming is an expensive management measure and some time it does not work properly. Selection of crops tolerant to acidity is an effective tool to encounter the soil problem and breeding of such varieties is of specific importance for attaining higher productivity particularly in the areas where liming is not economical. Mandal *et al*., (1975) suggested some of the crop like maize, sorghum, wheat, barley, millets, rice, oats, field beans, soybeans, pea, lentil, *berseem,* groundnut, sugarcane, cotton and potato for acid soils. However, none of the information available on fenugreek in limed acid soils except Aishwath *et al*., (2016) who reported that fenugreek comes well with the soil pH 6.5-8.2 in well drained loams or sandy soils. Lot of work documented on nutrient management and other stresses tolerance in fenugreek (Aishwath *et al.*, 2010, Aishwath *et al.*, 2011, Aishwath and Lal, 2016 and Alhadi *et al.*, 1999). However, there is no specific research available for the degree of

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tolerance of acidity by the fenugreek. To take the initiative for sustainable and eco-friendly management of these soils, non-traditional crops like fenugreek was grown for evaluation of degree of tolerance to soil acidity created by liming, to create the pH gradients.

Material and methods

The field experiments were carried out under the Typic Haplustalfs during *Rabi* season of 2009-2010, 2010-2011 and 2011-2012 at ICAR-Research complex for Eastern Region, Regional station, Plandu, Ranchi, Jharkhand. The experiments were laid around 23.280274 °N and 85.412344 °E Latitude and Longitude, respectively. Climate of the Ranchi area characterized as Humid Subtropical type. The average annual rainfall of the area is 1430 mm, the most of it 85-90% receives from June to September and that is about 1100 mm. summer temperature ranges from 20 to 42 °C and winter from 0 °C to 25 °C. December and January are the coolest months with temperature dipping to the freezing point in some of the areas.

The treatments consisted of four levels of liming 25%, 50%, 75% and 100% of recommended dose of lime and these were compared with control (where no lime was applied) and neutral to alkaline soil at Ajmer for crop parameters. The treatments were replicated four times under Randomized Block Design. Fenugreek variety Ajmer Methi-1 (AFg-1) was used as a test crop and sown in 25 cm line apart. Recommended agronomic practices were adopted for cultivation of crop during all the three seasons. The crop was harvested on maturity and seed yield was calculated.

Soil analysis

Soil samples were collected from the surface (0-15 cm depth) before sowing. Samples were air dried and powdered with wooden mortar and pestle and passed through a 2 mm stainless steel sieve. Experimental soil was analyzed for physicochemical properties ie EC and pH (Richards, 1954), organic carbon content by rapid chromic titration (Walkley and Black, 1934), available N by alkaline permanganate (Subbiah and Asija, 1956), available P by 0.5 M $NaHCO_3$ extractable P (Olsen, *et al*., 1954) and Bray and Kurtz (1945), available K by 1N NH_4OAc extracts method (Jackson, 1973) and available micro-nutrients by DTPA (Lindsay, and Norvell, 1978).

Texture of experimental soil was sandy loam. Soil EC, pH and organic carbon were 0.92 dSm^{-1}, 4.78 and 0.46%, respectively. However, soil available N, P and K were 200, 18.12 and 505.5kg ha^{-1}, respectively. Micronutrient status like iron, zinc, manganese and copper of the soil was 94.9, 6.8, 85.8 and 7.11 kg ha^{-1}, respectively.

Plant analysis (Chemical and growth)

The plant samples were collected after the harvest of crop. These samples were successively washed with tape water, 0.1 M HCl there after distilled water and dried at 70^{o}C. After proper drying, samples were powdered in wily mill and passed through the 20 mesh steal sieve. Nitrogen was estimated by Kjeldahl method (Piper, 1966). The samples were digested in nitric and perchloric acid (10:4) for the estimation of P by Venado-molybdo yellow colour method (Chapman, and Pratt, 1962) and K by flame photometer. Micronutrients were analyzed by Atomic Absorption Spectrophotometer.

Statistical Analysis and Meteorological data collection

The data of all the years were analyzed by ANOVA and treatment differences were expressed for Least Significant differences (LSD) at 5% probability to determine the significance among the treatment means (Cochran and Cox, 1987). Meteorological data were obtained from observatory of ICAR-RCER Regional Station, Ranchi and ICAR-NRCSS, Ajmer and calculated the mean value during crop period. Correlation of seed yield with soil available nutrients and plant N content was also calculated by using MS Excel.

Results and discussion

Growth, yield and their parameters

Plant height, shoot dry weight and number of leaves were recorded at various stages of crop growth which showed that liming effect appeared more at juvenile stage than maturity. Moreover, at later stage, crop resist against the acidity and liming effect appeared marginal. Plant height and shoot dry weight was significantly enhanced by application of lime (Table 1). Numbers of leaves per plant were only higher at 100% RDL at various growth stages. Number of pods and root nodules per plant were more with all levels of RDL except 25 % (Table 2). However, seed, haulm and biological yield was higher at 100% RDL. Per cent seed yield increase with 25, 50, 75 and 100% application of RDL was 15.0, 17.5, 18.1 and 37.4, respectively. Seed yield was directly correlated with soil available N, P, K and seed N content, and their corresponding r^2 values were 0.90, 0.97, 0.89 and 0.94, respectively. Seed N content was also significantly correlated with available N, P and K and the r^2 value was 94, 91 and 86, respectively. The improvement in growth and yield might be due to change in soil chemical and biological properties. With rise in pH, solubility of aluminium and manganese decreases, both of which are toxic to plants in general. Plants vary in their tolerance of Al and Mn, creating crop-specific soil pH requirements. Adding lime increases soil pH (reduces acidity), adds calcium and/or magnesium, reduces the solubility of Al and Mn in the soil (Anderson, *et al.,* 2013). The crop yield

Table 1. Growth parameters of fenugreek with applied lime.

Treatments	Plant height (cm)			Shoot dry weight (g 10 plant^{-1})			No. of leaves plant^{-1}	
	At 50 DAS	At DAS	At maturity	At 50 DAS	At 75 DAS	At maturity	At 50 DAS	At 75 DAS
Control	25.0	47.3	72.5	10.8	38.0	61.3	30.2	64.8
25 % RDL	26.3	50.3	74.5	12.5	40.0	64.3	31.1	70.5
50 % RDL	28.4	50.1	75.3	13.5	40.8	64.8	32.3	70.9
75 % RDL	29.7	50.5	76.3	13.8	38.3	68.5	33.5	71.0
100% RDL	30.3	51.8	78.5	14.8	38.8	70.0	35.1	84.0
CD(0.05)	4.8	7.1	13.0	1.5	5.1	24.7	5.6	18.1

Table 2. Yield and yield parameters, nodulation and per cent disease index in fenugreek with lime.

Treatments	Pods plant^{-1}	Seeds pod^{-1}	Seed weight plant^{-1}	Seed yield (q ha^{-1})	Haulm yield (q ha^{-1})	Biological yield (q ha^{-1})	Nodules plant^{-1}	Per cent disease index
Control	13.8	10.5	3.25	8.52	20.5	29.0	9.2	25.5
25% RDL	14.4	11.5	3.26	9.80	23.5	33.3	10.4	25.5
50% RDL	15.5	12.5	3.75	10.01	24.0	34.0	11.3	27.5
75% RDL	16.3	13.8	3.75	10.06	24.2	34.2	12.6	28.3
100% RDL	16.3	13.5	4.00	11.71	28.1	39.8	14.1	30.3
CD at 5%	1.4	2.3	NS	2.71	5.0	9.2	1.2	3.0

was about 50% lower in acid soil than the neutral to alkaline pH. This is possibly because of function of rhizobia suppressed by acidity resultant poor nodulation and ultimately poor assimilation of N as evidenced by N content in plant (Fig. 1). Improvement in sugarcane yield and N content with quick lime reported by Choudhry (1984). Adverse effect of soil acidity on growth, yield, nodulation and N assimilation in alfalfa was also observed by Rice *et al.* (1977) when soil pH decreased below 6.0. In contrast to that, soil having pH 6.0 or greater, lesser the effect on above parameters was observed. Fenugreek also belongs to the alfalfa group/family of plant and also has similar galactogogue properties performed accordingly.

Disease incidence and relative humidity

Powdery Mildew disease was observed in all three years of experiments at Ranchi, whereas incidence does not frequent at Ajmer, an origin place of the variety. Disease index was increased with increase in lime and was only significant at 75 and 100% RDL (Table 2). This might be due to higher humidity during the crop period as compared to traditional growing areas of Rajasthan (Fig. 7). More disease incidence with higher pH may be one of the possible reason by which lower availability of Fe and Mn in soil consequently lower absorption by plant. PDI of powdery mildew was directly and inversely correlated with soil pH and available Mn, respectively and their corresponding r^2 values were 0.97 and -0.94. Lower Mn content in leaves and higher powdery mildew disease incidence with higher soil pH was also recorded by Brain and Whittington (2007). Besides the humidity and pH, Cu content in both seed and straw was more at origin of variety than Ranchi despite more availability in acid soils than neutral to alkaline soil (Fig. 5 & 6). Dordas (2008) elucidated the role of nutrients like K decreases the susceptibility of host plants up to the optimal level for growth and beyond this point there is no further increase in resistance. In contrast to K, the role of P in resistance was variable and seemingly inconsistent. Micronutrients play an important role in plant metabolism by affecting the phenolics and lignin content and also membrane stability (Graham and Webb, 1991). Among the micronutrients, Mn can control a number of diseases, as Mn has an important role in lignin biosynthesis, phenol biosynthesis, photosynthesis and several other functions. Temperature was more or less similar at Ajmer and Ranchi being on similar latitudinal plane, while there was a very wide variation in humidity at both the places (Fig. 7). The

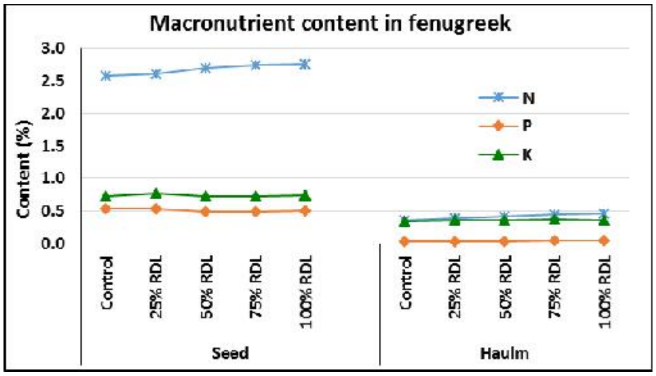

Fig. 1: Macronutrient content in seed and straw of fenugreek with lime

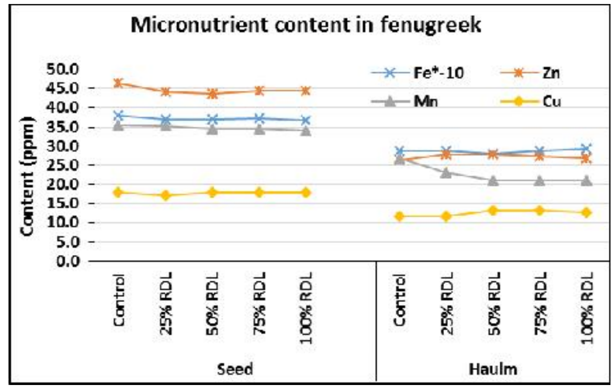

Fig. 2: Micronutrient content in seed and straw of fenugreek with lime

relative humidity at Ajmer was always < 50% during crop growth period, whereas at Ranchi it was 80-90% which was optimum for powdery mildew incidence. High humidity increases fast germination and development of conidia caused higher incidence of powdery mildew in crops (Quinn and Powell, 1982). Pap, *et al*., (2013) elucidated the influence of environmental factors in the complex relations that exist between the plant and its pathogen. They found germ tubes of powdery mildew begain to develop at all values of relative humidity (10-100%) and reached the maximum length at 90 per cent on leaves of oak.

Nutrient and protein content and uptake of nutrients

The N, P and protein content in both seed and halum was more with increased dose of lime (Fig. 1 and Table 3). Higher N content in sugarcane with liming was also recorded by Choudhry (1984). However, K content was more in halum only. Fe content in both seed and haulm marginally decreased with application of lime (Fig 2). Mn content in haulm decreased significantly with increase in lime doses and was marginally lower in seed. However, Fe, Zn and Mn content in both seed and straw was also more in acidic soil at Ranchi than neutral soil at Ajmer (Fig. 5 & 6). Patrick *et al.,* (1987) also reported that Fe and Mn content were pH dependent in rice and decreased with increase in pH. Besides the limed acid soil, nutrient content of fenugreek was also compared to the crop grown on neutral to alkaline soil at Ajmer. The N, P and K content in fenugreek was substantially lower in acid soil at Ranchi except P in seed (Fig 3 & 4). When P content in seed went down lower than thresh hold level under acid soil, which was compensated by translocation of P from straw to seed. Among macronutrients, P translocated in highest amount followed by K and N in acid soil than neutral soil. The reason of lower N content in both seed and straw in acid conditions as that of neutral, might be because of availability of molybdenum generally very low in acid soil due to fixation by hydrous oxides of aluminum and iron. Molybdenum is an essential component of nitrogenase enzyme controlling fixation of atmospheric N_2 to NH_3 by *Rhizobium* bacteria living symbiotically on the roots of legumes. Therefore, lack of availability of Mo reduces N fixing capacity and plant often shows N deficiency symptoms (Walters, 2016). The P content in seed was maintained by translocation from halum to seed. This is an adaptive strategy by the crop. Such as P play a crucial role in energy transfer during germination and early growth stage requires a definite amount of P, reason by P transferred from straw to seed and maintained the content in seed as that of neutral to alkaline soil. The K content was much higher in stover under neutral to alkaline soil than the acidic, is also an adaptive mechanism with soil pH. Uptake of N, K, Cu and Zn was higher with all the fractions of RDL. P uptake was higher only at 75 and 100% RDL and Fe at 100% RDL, while Mn was marginal. It is obvious that more of the yield and more content of some of the nutrients with higher level of lime leads to more uptake.

Soil available nutrients

Availability of N, P and K was marginally improved with increased levels of lime (Table 4). More number of nodules with liming (Munns, 1968) leaves more N in soil after decay and fast mineralization of soil organic matter (SOM) with lime releases more N in soil. Marginally improvement of N in soil and plant N content was also noticed by Choudhry (1984). Haynes (1992) described that adsorption of phosphate by amphoteric soil surfaces generally decreased slowly as the pH increased from 4.0 to 7.0. He also stated that liming can increase phosphate availability by stimulating mineralization of soil organic phosphorus. However at the higher liming rates of 100 % RDL the available P reduced. Similar results were obtained by Bartlet and Picarelli (1973). Fe, Zn and Mn availability decreased marginally with increase in lime doses. However, available Cu showed inconsistent change with the increase in liming. The inconsistent findings of Cu

Table 3. Protein content and nutrient uptake by fenugreek under limed acid soils of Jharkhand

Treatments	Protein (%)		Uptake (kg ha^{-1})			Uptake (g ha^{-1})			
	Seed	Haulm	N	P	K	Cu	Fe	Mn	Zn
Control	16.7	2.8	26.0	4.2	10.7	31.5	765.6	70.9	70.9
25% RDL	16.9	3.0	29.6	4.7	12.9	37.2	864.3	70.9	88.8
50% RDL	17.2	3.1	30.1	4.8	13.0	40.6	878.0	73.4	89.6
75% RDl	17.3	3.3	30.9	5.3	13.1	40.6	889.5	76.6	89.2
100% RDL	17.5	3.4	36.6	5.9	15.1	45.0	1051.4	84.4	104.6
CD at 5%	0.6	0.3	0.8	0.9	2.1	5.6	171.6	NS	16.0

Table 4. Soil EC, pH, SOC and available nutrients after fenugreek under lime acid soils of Jharkhand.

Treatments	Available macro and micronutrient (kg ha^{-1})							EC (dSm^{-1})	pH (1:2.5)*	SOC (%)
	N	P	K	Cu	Fe	Mn	Zn			
Control	205.9	18.0	511.3	7.5	96.9	86.1	6.8	0.92	4. 8	0.48
25% RDL	207.1	18.3	511.5	7.6	94.5	85.4	6.7	0.94	5.1	0.47
50% RDL	208.9	18.6	512.1	7.6	94.1	85.1	6.7	0.95	5.4	0.46
75% RDl	210.1	18.8	513.4	7.8	93.5	84.9	6.6	0.96	6.0	0.45
100% RDL	211.1	19.5	514.6	7.6	92.9	83.7	5.9	0.97	6.5	0.44
CD at 5%	NS	NS	NS	NS	NS	NS	NS	0.03	0.29	0.02

*Soil : water suspension, SOC = Soil Organic Carbon

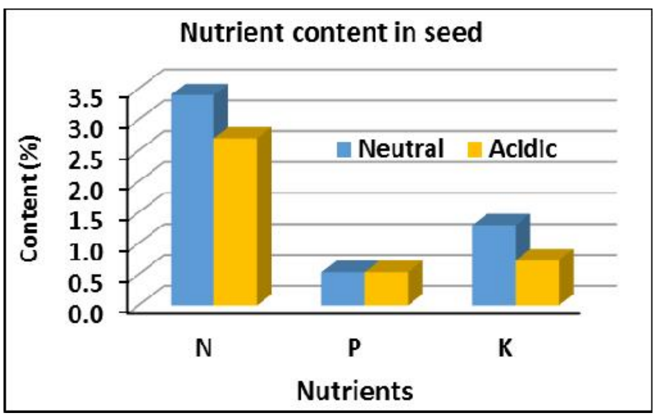

Fig. 3: Macronutrients content in fenugreek seed under neutral and acidic soil conditions

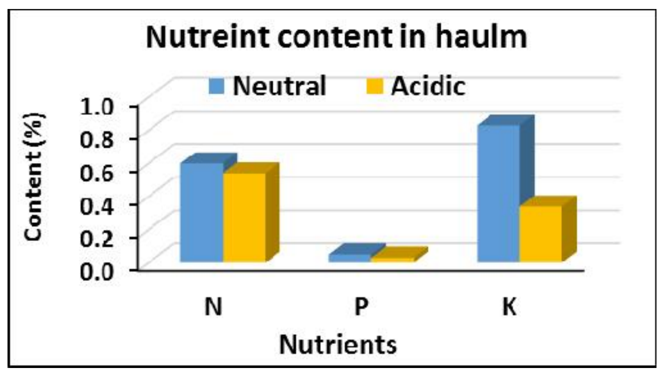

Fig. 4: Macronutrients content in fenugreek haulm under neutral and acidic soil conditions

with lime were also reported by Buni (2014). However, Pritam and Rai (1989) explained about the reduced availability of iron and manganese on acid soil with liming due to precipitation of Fe and Mn in the forms of carbonates, oxides or hydroxides as a result of increase in pH. Liming improved both EC and pH beyond 50% of RDL. It is because of lime released the hydroxyl ion and consequently other electrolytes raised pH and EC dSm^{-1}. Contrary to the EC and pH, soil organic carbon content decreased with increase in soil pH. This might be due to the fact that microbial action enhanced with rising pH towards the neutral side and ultimately mineralization of organic matter increased (Choudhry 1984). The fast mineralization of organic matter was also a possible reason for improvement in soil available N, P and K with liming and vice versa.

Conclusion

In acid soils of Eastern Plateau Hill Region, macronutrients are the most limiting factors for fenugreek

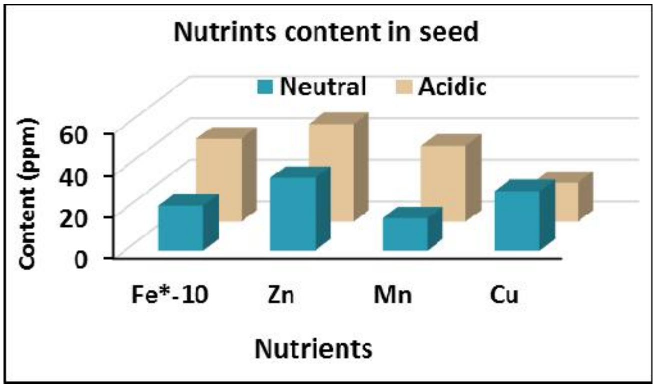

Fig. 5: Micronutrients content in fenugreek seed under neutral and acidic soil conditions

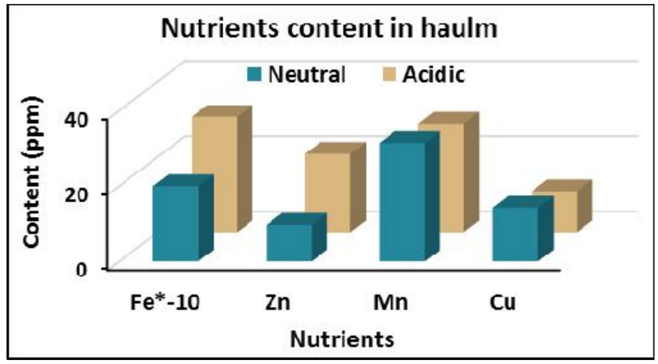

Fig. 6: Micronutrients content in fenugreek haulm under neutral and acidic soil conditions

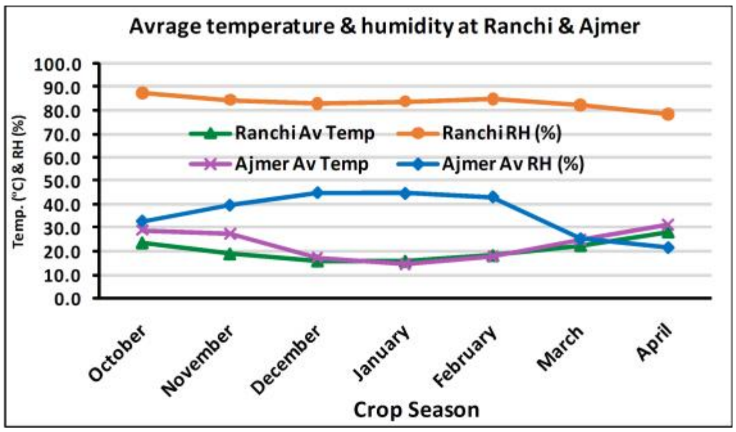

Fig. 7: Average temperature and relative humidity at Ranchi and Ajmer during crop season

productivity and powdery mildew disease was also an equally important limiting factor. Soil pH, humidity and nutrient content in both soil and plant were directly related to crop yield and disease incidence. Mn content in plant and soil played a crucial role to suppress the powdery mildew disease in fenugreek under acid soil and Cu under neutral to alkaline soil among the micronutrients. Soil chemical properties were improved, but SOC content decreased with liming. Hence, fenugreek could be grown in eastern plateau hill region with compromising about half of the seed yield.

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