Indian Journal of Agricultural Sciences **86** (2): 202—7, February 2016/Article

Strategy for application of macro-, micronutrients and liming in acid lateritic soils of Jharkhand for sustainable growth of *Flemingia semialata*

S GHOSAL[1], S C MEENA[2], J GHOSH[3] and K THAMILARASI[4]

ICAR- Indian Institute of Natural Resins and Gums, Ranchi, Jharkhand 834 010

Received: 18 November 2014; Accepted: 6 August 2015

ABSTRACT

An experiment was carried out during 2011-12 to 2013-14 at the Institute Research Farm, Ranchi (23°23'N longitude, 85°23' E latitude and 650 m above MSL) to study the effects of different primary nutrients, liming and micronutrients (boron, molybdenum, zinc and copper) on the growth of 5 year old established plantation of *semialata* (*Flemingia semialata*) and residual effect on soil fertility. The experiment consisted of 12 treatments. These included recommended doses of zinc, copper, boron, molybdenum, liming @ 125 g/m^2, two doses of potassium (30 and 60 g/ plant), two doses of nitrogen (25 and 50 g/plant), combination of N-P-K (50, 25 and 50 g/ plant) and two control treatments (lac inoculated and lac un-inoculated) replicated thrice and was conducted in Randomized Block Design. Effect of year was separated by analyzing variance due to years adopting factorial mode. Treatments like liming, nitrogen application (50 g) and NPK combination (50-25-30 g) excelled by producing 1.47, 1.42 and 1.48 kg fresh biomass/plant as against 1.23 kg in control (inoculated). Boron, zinc, potassium and copper application occupied a position in the middle order (1.28 to 1.36 kg). Plant mortality significantly went down to merely 5% on third year as against 30% in first year. It indicated that cumulative effect of imposition of treatment in present rate on the experimental plot has benefited the plant stand significantly. Copper level increased to 3 ppm in copper applied treatments which was approximately three times more than that of normal soil. Similarly, zinc content was raised to 2.52 ppm on the plots where zinc was applied. Potassium application at higher rate has increased the soil potassium level 23%, suggests that loss of potassium from this soil is very negligible. Study also revealed that only four parameters varied markedly due to liming. These were $CaCO_3$ content, potassium and manganese level and soil pH. Lower rate of liming (14 lime/ha/year) proved to be efficient and remunerative; it could raise the pH 0.33 unit.

Key words: *Flemingia semialata,* Liming, Macro and micronutrients

In general, 30% of the geographical area of the country is acidic, out of which 60% falls in the category of moderately acidic to strongly acidic. The status of Jharkhand state is still worse. Out of 79.7 lakh hectare total geographical area, 92% comes under acid soil, out of which 49% comes under strongly acid to extremely acid condition. Soil acidity leads to low soil fertility condition. Forty seven per cent of the total area of the state comes under low organic carbon content (0.5%), 89.6% under low to medium available N content (< 560 kg/ha), 66% area under low phosphorus content (0-10 kg/ha) and 69% under low to medium status of available potassium content (< 280 kg/ ha). Therefore soil acidity is an inherent problem of the area and requires serious attention (Anonymous 2014).

Due to soil acidity, availability of all major nutrients and micronutrients like boron and molybdenum gets affected. At the same time, the availability of micronutrients like iron aluminum, manganese etc increases significantly which restricts root growth and ultimately the plant growth suffers (Mandal *et al.* 2004, Tanaka and Navasero 1966).

Flemingia semialata, an important member of Leguminosae family is a perennial bushy lac host. Its growth habit varies widely depending upon the soil type. In Ranchi soils (lateritic) it becomes ready for lac cultivation in one year; while it was reported to be ready for lac cultivation in six months only in the alluvial soils of West Bengal (Anonymous 2010). First few years, plants grow satisfactorily. Afterwards its growth starts declining; newly emerged shoots become thin and total plant biomass production reduces and becomes less remunerative for lac cultivation. There is another way by which the plantation gets damaged due to poor growth, i.e. coincidence of pruning time and period of moisture stress in February to April (Singh *et al.* 2011). Many newly emerged shoots die due to lack of water during April. Therefore, all macronutrients (nitrogen, phosphorus and potassium) and micronutrients like boron and molybdenum are expected to play a vital role in governing its growth. Earlier work from this Institute reported (Anonymous 2005) that copper and

[1]Principal Scientist (e mail: soumen66iinrg@gmail.com), [2]Scientist (e mail: scmeena.iinrg@gmail.com) [3]Senior Scientist (e mail: jghoshranchi@gmail.com) [4]Scientist (e mail: ktarasi@yahoo.co.in), Lac Production Division

zinc might have some role to play in increasing lac production on *kusum* (*Schleichera oleosa*).

Therefore, it was felt to evaluate which nutrient contributes much for its growth. It was also important to assess the rate of reduction in plant vigour and how far soil fertility is responsible for this degradation. Side by side, the study also had objective to see the fate of nutrients / soil amendments after its application. This study generated information regarding relative vulnerability of different nutrient elements to loss from soil and also the most remunerative rate of liming.

MATERIALS AND METHODS

For evaluating the effect of application of different macro/ micro nutrients and liming on growth of *F. semialata* plants and its influence on soil fertility, an experiment was conducted at Institute Research Farm, Namkum (23^{o}23'N longitude, 85^{o}23' E latitude and 650 m above MSL) during 2011-12 to 2013-14 in a plantation of five year old. The experiment was laid out in Randomized Block Design with 12 treatments replicated thrice. The treatments included recommended doses of zinc, copper, boron, molybdenum; liming @ 125 g/m^2, two doses of potassium (30 and 60 g/ plant), two doses of nitrogen (25 and 50 g/plant), combination of N-P-K (50, 25 and 50 g/ plant) and two control treatments (lac inoculated and lac un-inoculated, i.e. C1 and C2) in. Each plot received only one treatment. No other nutrient and/ or growth supplement was used for improving crop health in general. Main purpose to include uninoculated control was to compare differences of growth due to inoculation of lac.

All micronutrients and full dose of phosphorus and potassium and half dose of nitrogen were applied at the onset of monsoon and rest half dose of nitrogen was applied during third week of August. Liming was done two months before monsoon. Sources of fertilizer were diammonium phosphate and urea for nitrogen and phosphorus, muriate of potash for potassium. For application of micronutrients, zinc sulphate and copper sulphate @ 25 kg/ha for zinc and copper respectively, borax @ 10 kg/ha for boron and sodium molybdate @ 1.00 kg/ha for molybdenum were used during the study. All the micro nutrients were used for first year only while macronutrients and lime application was done all the years. The purpose of putting macronutrients, micronutrients and liming in a single experiment was to evaluate relative importance of these factors in acid lateritic soil of Ranchi.

Availability of micronutrients varies widely due to change in pH. Therefore, a separate experiment was launched with four micronutrients, i.e zinc, copper, boron and molybdenum in recommended dose along with control, applied in *F. semialata* field under different levels of liming (0, 1.4, 2.8 and 4.4 tonnes/ha.) to visualize the effect on plant growth and residual soil fertility.

Kusmi lac was inoculated in July in all the three years. Shoots without insect settlement were collected for studying dry matter per cent. Plant growth performance due to imposition of different treatments was examined through estimation of Chlorophyll Content Index (CCI) at different plant growth stages, shoot dry matter per cent, production of thick shoots and plant biomass (fresh weight) at harvest. Dry weight of such shoots was recorded by subjecting the shoots to dry in oven at 65^{o}C temperature until a constant weight was obtained. Whole plant along with lac was harvested in the month of February every year.

Lac producing ability of shoot depends upon its thickness. Therefore, proportion of shoots (per cent) more than 10 mm thickness or more were recorded to have an impression on the effect of the treatment on lac productivity.

Soil collected from each treatment was analyzed for nineteen parameters of different soil physicochemical characters. Pooled analysis was done to get an overall mean of treatment as well as overall mean of the year along with their critical difference values. Statistical analysis of data for both the experiments was done in Randomized Block Design.

RESULTS AND DISCUSSION

Effect on plant growth

For evaluating effect of different macro/micronutrients on growth of *F. semialata*, observations on growth attributes like Chlorophyll Content Index (CCI), per cent thick shoots ($\geq$10 mm basal diameter), plant height, nodule number and plant biomass (fresh weight) were recorded. Pooled analysis result has been presented in Table 1.

Results indicated that out of five monthly observations on CCI (September to January) only in two occasions the difference due to treatments touched the level of significance (Oct and Nov). Nitrogen application @ 50 g/ plant proved to be the best treatment assuming a value of 23.1 in the month of October. Perusal of data revealed that only N application @ 50 g/ plant has got some moderate effect on CCI as it could increase CCI values 34% over control. But in later stages, it came at par to control.

Treatments which were at par to uninoculated control are supposed to be good ones due to their ability to perform even under lac inoculation condition. Therefore, uninoculated treatment (without insect load) is supposed to be the best treatment. Application of lime, boron, nitrogen (25g) and NPK combination proved to be better treatments in producing higher proportion of thick shoots and were at par to uninoculated control. Values ranged in between 40 to 44%. Positive effect of lime and boron application was reported earlier from Jharkhand (Singh *et al.* 2002). On the other hand, performance of zinc, copper, molybdenum, potassium, nitrogen (50 g) along with control (inoculated) were inferior remaining at par to each other so far as thick shoot production is concerned.

Dry matter per cent is an important character of shoot governing lac productivity. Lesser the dry matter per cent, higher the production potentiality of the host. In the present study, application of boron, potassium, nitrogen (50 g), NPK combination and uninoculated control could produce

Table 1 Growth attributes of *F. semialata* as affected by application of different macro and micronutrients in different years

	Biomass (kg)	CCI Oct	CCI Nov	Plant height (cm)	% shoots more than 10 mm thickness	DM (%)	Plant mortality (%)
2011-12	1.54	17.3	15.7	153.4	42.2	28.9	30.61
2012-13	1.35	18.3	22.4	171.5	39.1	24.6	–
2013-14	1.11	23.1	17.8	173.2	36.0	26.4	5.48
CD (P=0.05)	0.11*	1.0*	0.9*	6.5*	4.1*	0.7*	2.87*
C1	1.23	17.2	20.2	154.5	31.5	27.3	8.43
Zn	1.36	19.8	18.1	171.7	37.2	26.8	12.67
Cu	1.29	19.3	19.5	169.5	37.3	26.8	12.13
B	1.30	19.0	17.7	173.0	43.4	25.9	10.87
Mo	1.19	18.0	17.0	168.5	36.8	27.3	11.15
Lime	1.47	19.9	17.4	167.3	42.4	28.8	10.88
K_{30}	1.28	20.1	17.8	167.6	38.0	25.2	14.09
K_{60}	1.18	19.2	19.2	161.3	38.2	25.6	13.39
N_{50}	1.42	23.1	20.4	161.8	38.4	26.0	11.56
N_{25}	1.19	20.7	17.3	168.6	44.2	27.8	11.76
$N_{50}P_{25}K_{50}$	1.48	20.5	18.9	167.1	41.7	25.7	15.75
C2	1.58	18.2	20.3	161.7	40.0	26.4	11.66
CD (P=0.05)	0.21*	2.0*	1.9*	13.1	8.1*	1.4*	5.73

*Significant at 5% level

shoots of relatively lower dry matter with values ranging from 25.2 to 26.4%. Since, K_2O helps in efficient translocation of assimilates and maintains water relation in the cells, shoot succulence increases considerably (Ghosal 2012), the treatments like application of potassium and NPK combination performed well. Moinat (2014) concluded that succulence or tenderness and turgidity of tissue are correlated with optimum boron nutrition and water supply, which result in rapid growth and large thin walled cells. Both higher and lower concentration lowered the moisture content of plant shoot. This could be the reason for better performance of boron application. Less performing treatments were liming and nitrogen application @ 25 g/ plant.

Performance of any treatment is best reflected through biomass production ability of plant. Maximum biomass production was recorded in uninoculated control (1.58 kg/plant) which was at par to other treatments like liming, nitrogen application (50 g) and NPK combination. Thus liming emerged to be the most realistic and economic measure for improving the soil of Jharkhand to make it suitable for lac cultivation on *semialata*. An increase of 19.5% in fresh weight was observed due to lime application in comparison to control. Boron, zinc, potassium and copper application occupied a position in the middle order. Fuentes *et al.* (2006) concluded that higher soil pH promoted greater respiration rates and greater microbial biomass carbon in lime-treated than in non-limed soils. Faster turnover rates and increased mineralization of organic matter were found in lime-treated than in non-limed soils. Rise in pH and greater microbial activity might have facilitated higher release of mineral nutrients. Higher plant biomass could be the effect of better nutrition condition of the soil. Ghosal (2013) reported similar results on *Ziziphus mauritiana*.

Significant variation in plant mortality was not observed due to treatment differences. But difference between the first year and third year was significant. On first year just after the imposition of treatment, rate of plant mortality was quite high, i.e. 31% of total plant population (Table 1). Plant mortality significantly went down to merely 5% on third year. It indicated that cumulative effect of imposition of treatment in present rate on the experimental plot has benefited the plant stand significantly. Over the years a significant change in the levels of phosphorus, potassium and pH was observed during the study. Maximum change was observed in case of pH, which increased to 4.5 from 3.9 during the study. Therefore, study concluded that these three soil parameters played a vital role in checking plant mortality significantly.

Separate experiment on different rates of liming revealed that Chlorophyll Content Index increased steadily in December due to liming up to 2.8 tonnes/ha. However, per cent shoots with more than 10 mm diameter went on increasing up to highest level, i.e. 4.4 tonnes/ha. Plant fresh weight was not influenced by liming. It signified that shoot diameter is not a very important factor which can govern fresh weight dramatically. Micronutrient application under different liming condition did not prove to be effective on any of the growth factors like CCI values, dry matter per cent, plant height etc (Table 2). Thus, it can be concluded that higher rates of liming are not useful due to quick drain out of lime in rain water when small scale application is done.

Table 2 Growth characters and lac yield and yield attributes as affected by rates of liming and micronutrient application

	CCI Dec	CCI Jan	% shoots with ≥ 10 mm diameter	Fresh wt/ plant (kg)
L0	13.76	13.54	65.5	1.0
L1	14.84	13.59	63.2	1.2
L2	15.54	14.06	66.3	1.1
L3	14.09	13.19	73.5	1.3
CD (P=0.05)	1.25*	1.56	4.9*	0.3
C	13.51	13.26	66.4	1.1
Zn	14.84	13.78	63.0	1.3
Cu	14.87	14.15	67.7	1.1
B	15.24	13.64	68.9	1.1
Mo	14.33	13.14	69.7	1.1
CD (P=0.05)	1.39	1.75	5.5	0.3

*Significant at 5% level, C: Control, L1, L2, L3 and L4 represent liming @ 0, 1.4, 2.8 and 4.4 tonnes/ ha lime application.

Table 3 Residual soil fertility level as affected by application of different macro and micro nutrients in different years

	Boron (mg/kg)	Calcium (mg/kg)	$CaCO_3$ (%)	Chloride (mg/kg)	Copper (mg/kg)	EC (dS/m)	Fe (mg/kg)	K (kg/ha)	Mg (mg/kg)	Mn (mg/kg)	Molybdenum (mg/kg)	Nitrogen (kg/ha)	Na (mg/kg)	OC (%)	P (kg/ha)	pH	Sulphur (mg/kg)	WHC	Zinc (mg/kg)
2011-12	0.67	462.2	0.91	5.30	1.41	0.17	74.5	147.6	309.3	46.8	2.36	206.9	253.9	0.45	29.0	3.9	27.1	39.7	1.22
2012-13	0.64	511.1	0.52	4.30	1.12	0.21	64.2	239.1	250.7	36.2	0.12	271.6	218.3	0.57	28.0	4.5	28.1	43.2	1.25
2013-14	0.67	735.6	0.28	8.72	1.08	0.15	85.0	265.8	350.6	55.9	0.15	211.4	303.6	0.46	32.3	4.5	18.1	38.6	1.10
CD (P=0.05)	0.11	36.1*	0.12*	0.89*	0.21*	0.02*	9.2*	13.9*	24.0*	3.9*	0.36*	15.7*	21.0*	0.03*	2.7*	0.1*	3.3*	1.3*	0.17
C1	0.59	551.1	0.59	6.62	1.06	0.17	59.2	197.2	288.0	47.3	0.52	218.4	257.8	0.46	27.5	4.3	28.4	41.5	1.13
Zn	0.67	497.8	0.59	6.18	1.02	0.17	57.4	209.4	288.0	44.6	0.87	214.7	271.1	0.47	29.9	4.3	25.0	42.0	2.52
Cu	0.52	604.4	0.58	7.06	3.00	0.15	55.6	216.2	320.0	40.1	0.60	224.7	253.3	0.48	31.4	4.4	25.4	43.1	0.92
B	0.57	604.4	0.44	4.86	1.09	0.17	75.3	223.4	298.7	44.0	0.95	239.0	268.9	0.51	30.7	4.5	27.7	40.4	1.15
Mo	0.58	551.1	0.77	6.18	1.17	0.17	75.2	214.4	298.2	45.9	0.87	212.2	293.3	0.46	31.4	4.2	21.5	39.5	1.02
Lime	0.77	586.7	0.57	6.18	0.96	0.17	63.0	221.6	298.7	44.8	1.47	233.4	286.7	0.50	28.8	4.5	21.7	39.9	0.92
K_{30}	0.62	622.2	0.70	5.74	1.00	0.18	70.8	243.5	298.7	49.6	0.79	227.8	268.9	0.49	28.7	4.5	22.8	38.2	1.18
K_{60}	0.76	551.1	0.66	5.08	0.97	0.22	68.6	271.6	298.7	46.8	1.37	233.4	271.1	0.50	27.8	4.6	25.5	41.1	0.99
N_{50}	0.68	586.7	0.50	6.62	1.11	0.19	90.6	186.6	320.0	48.4	0.71	234.0	213.4	0.50	27.2	4.1	24.5	41.2	0.99
N_{25}	0.68	533.3	0.50	6.18	1.08	0.17	100.1	205.2	309.3	49.1	0.90	234.6	262.2	0.50	28.4	4.1	23.1	40.0	1.39
$N_{50}P_{25}K_{50}$	0.58	586.7	0.51	6.18	1.04	0.20	106.7	222.7	320.0	48.0	0.54	236.5	222.2	0.50	30.5	4.1	24.4	39.2	0.97
C2	0.9	560.0	0.5	6.40	0.94	0.19	72.1	198.1	304.0	47.2	0.94	251.4	234.4	0.5	35.1	4.4	23.5	39.8	1.1
CD (P=0.05)	0.2	72.1	0.2	1.78	0.42*	0.04	18.5*	27.8*	48.0	7.7	0.71	31.3	42.1	0.1	5.4	0.3*	6.5	2.5	0.3*

*Significant at 5% level.

Effect on soil fertility

Significant change in residual soil fertility status in relation to copper, iron, potassium, soil pH and zinc content of soil was observed due to application of different macro/micronutrients during the study (Table 3). Copper level increased to 3 ppm in copper applied treatments which was approximately three times more than that of normal soil. Similarly, zinc content was raised to 2.52 ppm on the plots where zinc was applied. No significant change in boron and molybdenum level was noticed due to its application. However, it is worthwhile to mention that liming could increase 33% of boron and 300% of molybdenum in comparison to control, though it could not touch the level of significance. Keren and Gast (1983) concluded that at higher pH levels (>6.0) competition between OH^- and $B(OH)^{4-}$ for adsorption sites increases and the amount of adsorbed boron declines. Therefore, residual value was much due to liming than due to soil application of these individual elements.

Management of soluble iron in acid soil is a very important strategy for successful agriculture. Iron solubility increased significantly due to acid forming macronutrients (nitrogen, phosphorus). An increase of 31-47 ppm of iron was observed due to acid forming macro nutrients or in combination. Increase in soil acidity is the after effect of its application. As a result, soil pH has gone down 0.2 unit as compared to control. The reaction responsible for the reduced solubility of Fe with increasing pH is well understood. It results in the precipitation of $Fe(OH)_3$ as the concentration of OH^- ion increases. The $Fe(OH)_3$ is chemically equivalent to hydrated oxide, $Fe_2O_3.3H_2O$. Acidification shifts the equilibrium, causing a greater release of $Fe3^+$ as a soluble ion. Thus addition of nitrogenous fertilizers increased soil acidity which eventually increased iron solubility (Barak *et al.* 1997).

Potassium application has got a great significance in Ranchi soil. Its application @ 30 and 60 g/plant gave a residual value of 244 and 272 kg/ha, as against 197 kg/ha in control. All these values were remarkably different from each other. Potassium availability is hardly dependent on soil pH. In acid soil, concentration of aluminium ions increases and makes potassium free to come in soil solution. While in higher pH obtained due to liming, the calcium does the same job. Iron and aluminum level of the soil are supposed to be high as soil pH of the plot (4.5) was very low (Tanaka and Navasero 1966). Therefore, level of soil potassium increased after application.

To examine how soil fertility was affected due to liming and application of different micro

Table 4 Soil fertility level as affected by rates of liming and micro nutrient application

	$CaCO_3$ (%)	Copper (mg/kg)	K available (kg/ha)	Mn available (mg/kg)	Molybdenum (mg/kg)	Nitrogen (kg/ha)	OC (%)	P avail (kg/ha)	pH	Zinc (mg/kg)	Boron (mg/kg)
L0	0.31	1.16	254.3	49.5	0.12	204.1	0.44	33.6	4.53	1.1	0.42
L1	0.19	0.99	296.4	52.6	0.08	230.3	0.49	34.3	4.86	0.9	0.45
L2	0.59	1.17	334.2	63.8	0.10	207.9	0.45	38.1	4.78	1.0	0.66
L3	0.26	1.20	255.7	57.8	0.08	192.9	0.45	39.0	4.91	5.2	0.56
CD	0.20*	0.28	37.2*	5.9*	0.06	32.7	0.05	4.1	0.22*	5.0	0.17
C	0.39	1.01	283.6	52.5	0.08	224.7	0.48	35.3	4.76	1.1	0.55
Zn	0.26	1.04	253.5	58.9	0.10	187.3	0.44	34.7	4.67	1.4	0.53
Cu	0.25	1.49	287.1	57.8	0.10	201.3	0.44	35.0	4.84	0.8	0.46
B	0.36	1.09	303.0	57.4	0.10	220.0	0.48	40.7	4.79	0.9	0.51
Mo	0.43	1.01	298.5	53.0	0.09	210.7	0.46	35.5	4.80	6.2	0.56
CD	0.23	0.31	41.5	6.5	0.07	36.5	0.06	4.5	0.25	5.6	0.19

NB: L1, L2, L3 and L4 represent liming @ 0, 1.4, 2.8 and 4.4 tonnes/ha lime application and C: control.

nutrients, soil samples were analyzed for 19 parameters (Table 4). Study revealed that only four parameters varied markedly due to liming. These were $CaCO_3$ content, potassium and manganese level and soil pH. Approximately, two times increase in $CaCO_3$ content was observed due to liming @ 2.8 tonnes/ha as compared to control. Remarkable change in soil potassium and manganese level was noticed due to liming @ 2.8 tonnes/ha. Approximately, 31 and 28% increase in the values was observed due to liming in above rate, respectively. Values of pH also showed rise due to different rates of liming.

Liming could influence only few parameters which are discussed above. Other parameters including nitrogen and phosphorus remained unaffected. The main reason behind the phenomena is that the change in soil pH was not of a high magnitude, though difference was significant. In our earlier experiences it was observed that significant change in soil fertility takes place only when pH changes significantly (above pH 5.6). The rates of liming tried in this experiment are sufficient enough to change soil pH significantly. But, it failed to do so. The main reason behind the phenomena is that application was not at large scale. Therefore, its effect got diluted due to rapid wash out in the monsoonal rain. Rate of rise in pH was maximum due to the first dose, i.e. 14 quintal lime/ha which could raise the pH 0.33 unit. Therefore, farmers should follow the lower rate of liming for small scale/ localized application.

Future strategy

Biomass production continued to decrease steadily over the years. In first year per plant biomass production was 1.54 kg/plant, which decreased to 1.11 kg/plant marking a drop of 28% in two years time period. Similar findings have been found in case of proportion of shoots more than 10 mm. diameter.

While considering the NPK content of soil, it may be put in medium category. Practice of application of different macro/ micronutrients and soil amendments for three years, significant change was noticed in relation to soil pH, iron, phosphorus, copper and $CaCO_3$ content of soil. The pH has increased significantly, but still remained in strongly acidic range, which impaired uptake of majority of the elements. Significant reduction in $CaCO_3$ content of soil might have played a significant role in limiting the plant growth in the third year (Mandal *et al* 2004). Besides, in acid soil, solubility of iron and aluminum increases markedly, which restricts root growth of plants. Data also supported that iron availability has increased 14% within 2 years. This could be another aspect for poor plant growth in existing agriculture practice.

Therefore, in Jharkhand growers of *semialata* may adopt liming as per present rate, i.e. 14 quintal per hectare for maintaining soil fertility on small scale basis. Sustainable growth which can be addressed partially by soil fertility management should be taken up through other crop management practices also.

Application of potassium (30-60 g), nitrogen (50 g), N-P-K combination (50-25-50 g) per plant and boron (10 kg borax/ha) proved to show its superiority in producing succulent shoots as 1.3 to 2.1% lower shoot dry matter per cent was observed compared to control. Treatments like liming (125 g), N-P-K combination (50-25-50 g) and nitrogen (50 g) were superior as they could produce comparable biomass to uninoculated control (1.58 kg/plant). Plant mortality also decreased significantly within three years of time (from 30% to 5%). It was found that liming @ 1.4 tonnes/ha/year is the most remunerative rate for small scale application. Further, potassium, molybdenum and boron level increased (23-38, 300 and 33% respectively), due to liming.

ACKNOWLEDGEMENTS

Authors are thankful to Dr R Ramani, Director, ICAR-IINRG for his inspiration and motivation, Dr K K Sharma, Head, Lac Production Division for his valuable inputs during preparation of the manuscript. Shri K A Nagruar and Shri Binod Kumar are also acknowledged for their sincere cooperation in technical assistance.

REFERENCES

Adams F. 1984. Crop response to lime in the southern United States. *Soil Acidity and Liming,* pp 211—65. Adams F (Ed). American Society of Agronomy, Inc., Madison, WI.

Anonymous 2005. *Annual Report 2005-06, Indian Institute of Natural Resins and Gums, Ranchi,* p 19.

Anonymous, 2014. Soil acidity and fertility status: Jharkhand– an overview. Downloaded from http://www.sameti.org/jharkhand-state.pdf on 10.11.2014.

Anonymous, 2010. *Report 3 Lakshya Lakhsha*. International Mass Awareness Programme p 5. Gangcha, Pandua, Paschim Madinipur.

Barak P, Jobe B O, Krueger A R, Peterson L A and Laird D A. 1997. Effects of long-term soil acidification due to nitrogen inputs in Wisconsin. *Plant and Soil* **197**: 61—9.

Fuentes J P, Bezdicek D F, Flury M, Albrecht S and Smith J L. 2006. Microbial activity affected by lime in a long-term no-till soil. *Soil & Tillage Research* **88**: 123—31.

Ghosal S. 2012. Effect of weather and application of primary nutrients and liming to *ber* (*Ziziphus mauritiana*) on winter season (*aghani*) *kusmi* lac production. *Annals of Entomology* **30**(2) : 97—104.

Ghosal S. 2013. Soil fertility management of established *ber* (*Ziziphus mauritiana*) plantation under lac cultivation. *Bioscan* **8**(3): 787—90.

Keren R and Gast R G. 1983. pH dependent boron adsorption by montmorillonite hydroxy-aluminium complexes. *Soil Science Society of America Journal* **47**: 1 116—21.

Mandal Asit B, Basu Asit K, Roy Bidhan, Sheeza T E and Roy Tarak. 2004. Genetic management for increased tolerance to aluminum and iron toxicities in rice–A review. *Indian Journal of Biotechnology* **3**: 359—68

Moinat Arthur D. 2014. Nutritional relationships of boron and indoleacetic acid in head lettuce, Downloaded from www.plantphysiol.org on September 10, 2014.

Singh R K, Singh, Balram and Baboo, Bangali. 2011. Effect of *In-situ* soil moisture conservation practices on growth, moisture use efficiency and *kusmi* lac yield of *ber (Ziziphus mauritiana)* under rainfed condition in Jharkhand *Journal of Agricultural Engineering* **48**(3): 32—5

Singh R N, Kumar B, Prasad N K and Singh S. 2002. Effect of lime and boron application to maize *(Zea mays*)-gram *(Cicer arietinum)* sequence in soil of Jharkhand *Indian Journal of Agricultural Sciences* **72** (6) : 346—7.

Tanaka A and Navasero S A. 1966. Aluminum toxicity of the rice plant under water culture conditions. *Soil Science and Plant Nutrition* **12**. (2): 9—14.

Thomas G W and Hargrove W L. 1984. The chemistry of soil acidity. *Soil Acidity and Liming,* pp, 3—56. Adams F (Ed). American Society of Agronomy, Inc., Madison, WI.