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LIMING EFFECT ON SOME SOIL PROPERTIES IN CINNAMON (*Cinnamomum zeylanicum* Blume) GROWING SOILS: AN INCUBATION STUDY

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ABSTRACT

An aerobic incubation study was conducted to determine the liming effect on selected soil properties in three cinnamon (*Cinnamomum zeylanicum* Blume) growing soils in Matara district of Sri Lanka. Soil samples were collected from high (bark yield>700 kg $ha^{-1}yr^{-1}$), medium (bark yield 200-700 kg $ha^{-1}yr^{-1}$) and low (bark yield<200 Kg $ha^{-1}yr^{-1}$) yielding classes selected from Matara, Kamburupitiya and Weligama, respectively. A two factor factorial experiment using the three yield classes and four dolomite doses (D0 - no dolomite; D1 – 250 $kgha^{-1}$, D2 - 500 $kgha^{-1}$ and D3 – 750 $kgha^{-1}$) was established as an incubation study in a complete randomized design (CRD) with three replicates. Sampling was done three times with four-week intervals. At each sampling, soil pH, electrical conductivity (EC), total N, available P, exchangeable K, available S and soil respiration were determined by standard methods. In the case of dolomite levels, the highest pH and EC values were recorded in the D3 (750 kg Dolomite ha^{-1}) at 12 weeks. Soil respiration was increased rapidly in high, medium and low yielding sites at 12 weeks by 16.7, 40.1 and 83.4 %, respectively. Application of dolomite increased soil respiration in all dosages by 2.8, 5.3, 9.2 and 5.8 %, respectively, at 12 weeks. Total N, available P and exchangeable K increased in the high, medium and low yielding sites at the first, second and third sampling. The available S decreased in all sites and in dolomite treatments. Result revealed that liming enhances soil pH, EC and availability of soil nutrients (total N, available P, exchangeable K) except available S in cinnamon-growing soils studied.

Keywords: Soil incubation, Liming effect, Soil properties, Dolomite, Cinnamon

INTRODUCTION

Cinnamon is the dried bark of the perennial tree of *Cinnamomum zeylanicum* Blume of the Lauraceae family. Sri Lanka is the world's largest producer and exporter of "true cinnamon" contributing more than 90% of the world's true cinnamon trade. In 2011, the area of cultivation of cinnamon in Sri Lanka was 30,523 ha with an export volume of 13515.7 mt of quills, 231.2 mt of leaf oil and 30.1 mt of bark oil valued at Rs. million 14228.2 (Anonymous, 2012). Low crop productivity of cinnamon is a major problem in all cinnamon-growing areas in Sri Lanka due to several reasons. Soil reaction (pH) is one of the important soil properties that determine the crop productivity. Strongly acidic soils are usually depleted of bases such as calcium, magnesium, potassium, and sodium, where plants may not be able to obtain the quantities of those nutrients required for growth. Strongly acidic conditions also reduce the availability of phosphorus and molybdenum to the plant. Alkaline conditions reduce the availability of iron, zinc, copper, boron, manganese, and phosphorus to the plant (McCall and Watanabe, 1914). There are plenty of liming materials that can be used to neutralize soil acidity, however, majority of them comes from ground limestone such as calcite ($CaCO_3$) and dolomite ($CaCO_3.MgCO_3$) (Kovacevic and Rastija, 2010). The Department of Export Agriculture currently recommends application of dolomite at rate of 500 $Kgha^{-1}$ for cinnamon cultivation. The aim of this research was to study and compare the soil properties in three selected yield classes (high, medium and low) and the optimum rate of dolomite to provide the optimum level of nutrients for plant growth.

MATERIALS AND METHODS

The study was conducted at the National Cinnamon Research and Training Center, Palolpitiya, Thihagoda situated in the Matara district of Sri Lanka, during January to June, 2014. Out of the major cinnamon-growing districts, Matara is the second largest cinnamon growing district. Soil samples were separately collected from high (Matara), medium (Kamburupitiya) and low (Weligama) yielding sites according to the average cinnamon bark yield data for the past three years, which were obtained from relevant farmers. Visual observations were also considered. Soil samples were collected from 0-15 cm soil depth and one representative sample was prepared by making a composite sample taken from three points of each yield level to minimize sampling errors. Collected soils were used for the incubation study and for initial soil analysis. A two factor factorial experiment in a completely randomized design (CRD) was conducted in three replicates. The two factors were the bark yield (high yield > 700 $kgha^{-1}yr^{-1}$, medium yield 200 - 700 $kgha^{-1}yr^{-1}$, low yield < 200 $kgha^{-1}yr^{-1}$) and dolomite dosages (D0 - 0 $kgha^{-1}$, D1 - 250 $kgha^{-1}$, D2 - 500 $kgha^{-1}$ and D3 - 750 $kgha^{-1}$). Crushed dolomite was manually applied by mixing with soil in each pot. The data analysis was done by using (MSTAT-C) Software version 2.10 and Microsoft Excel 2007 package.

Aerobic incubation method

The soil was air dried and sieved through a 2 mm sieve prior to being weighed in 1500 g of soil samples that were transferred into plastic pots of 2 kg capacity. Amount of dolomite needed to each soil was calculated and sieved by using a 0.5 mm sieve before mixing with soil. After mixing dolomite, soil moisture was adjusted to 70 % of the water holding capacity, and the mixtures were incubated at room temperature for 3 months.

Sampling was done at 4th, 8th, and 12th weeks after incubation (WAI). Soil moisture was maintained during the incubation period by using gravimetric method. At each sampling date, pH, EC, Total N, Available P, Exchangeable K, and Available S of soil, and soil respiration were measured. The pH was determined by using a pH meter and EC was measured by using a conductivity bridge. The Total N was determined by the Kjeldahl method (Bremner, 1996) and available P by the Olsen's method (Jackson, 1973). The exchangeable K was measured by the neutral normal ammonium acetate method (Jackson, 1973) and available S by (Massoumi and Cornfield, 1963; Tabatabai, 1982). Soil respiration was determined by the CO_2 evolution method (Stotzky, 1965).

RESULTS AND DISCUSSION

Initial Soil properties

The initial soil properties measured from each yield class are shown in Table 1. At the initial stage, the highest pH, EC, total N, available P, exchangeable K, and available S were recorded in the high yielding soil while the highest soil respiration (CO_2 evaluation) was recorded in the low yielding soil. The lowest value of each chemical property (pH, EC, total N, available P, exchangeable K, and available S) and the highest soil respiration was found in the low yielding soil.

Changes in Soil pH

The soil pH as influenced by different treatments is presented in Table 2. Soil pH is a good indicator of the balance of available nutrients in the soil as well as microbial activity. The soil pH significantly varied ($p<0.05$) among yield classes as well as dolomite dosages used. Dolomite application raised soil pH in each low, medium and high yielding class throughout the incubation period. The high yielding soil class showed high mean pH value while the low yielding class recorded a low mean pH.

Table 1. Initial properties of the soil used in the experiments

Yield Class	Soil Properties						
	pH	EC ($dS\ m^{-1}$)	N (%)	P ($mg\ kg^{-1}$)	K ($mg\ kg^{-1}$)	S ($mg\ kg^{-1}$)	CO_2 evaluation ($mg\ day^{-1}$)
High	6.07±0.02	0.02±0.00	0.15±0.04	5.68±0.11	14.28±1.51	10.31±1.34	2.22±0.72
Medium	5.94±0.15	0.01±0.00	0.12±02	2.84±0.34	7.74±1.22	9.69±0.74	2.77±0.60
Low	4.27±0.49	0.01±0.00	0.10±0.14	1.42±0.15	6.55±0.43	8.13±0.70	3.30±0.95

The values are presented as mean ± standard error

Table 2. Effect of dolomite application and temporal variation of soil pH in different yield classes

Main Effect/Interaction	Soil pH		
Yield class	4 weeks	8 weeks	12 weeks
High	6.41^{a}	6.80^{a}	7.10^{a}
Medium	6.38^{a}	6.64^{b}	6.93^{b}
Low	5.91^{b}	6.14^{c}	6.43^{c}
Significance	***	***	***
(Dolomite dosages $kgha^{-1}$)			
0	5.67^{d}	5.74^{d}	5.80^{d}
250	6.10^{c}	6.42^{c}	6.84^{c}
500	6.34^{d}	6.78^{b}	7.08^{b}
750	6.84^{a}	7.17^{a}	7.52^{a}
Significance	***	***	***
(Interactions)			
High × 0	6.08^{cef}	6.11^{g}	6.12^{g}
High × 250	6.26^{cdef}	6.50^{e}	7.10^{cd}
High × 500	6.44^{cd}	7.04^{c}	7.32^{bc}
High ×750	6.84^{ab}	7.55^{a}	7.75^{a}
Medium × 0	5.95^{fg}	6.02^{g}	6.19^{g}
Medium × 250	6.16^{def}	6.47^{e}	6.89^{de}
Medium × 500	6.32^{cde}	6.84^{d}	7.14^{c}
Medium × 750	7.10^{a}	7.23^{b}	7.50^{d}
Low × 0	4.99^{h}	5.09^{h}	5.10^{h}
Low × 250	5.82^{g}	5.09^{f}	6.53^{f}
Low × 500	6.25^{def}	6.44^{ef}	6.78^{e}
Low × 750	6.58^{bc}	6.74^{d}	7.31^{bc}
Significance	**	***	***
CV %	13.0	10.5	12.9

Within a column, means followed by the same letter are not significantly different; *, **, *** significant at p=0.05, 0.01 and 0.001, respectively.

All dolomite resulted in a significantly higher pH ($p<0.05$) throughout the incubation period, compared to the control. High soil pH was observed in the treatment that received at the highest rate of dolomite (750 $kgha^{-1}$). There were significant interactions ($p<0.05$) among the treatment combinations of yield classes and dolomite dosages. The highest pH at four WAI was observed with the treatment combination medium yield class x 750 kg dolomite ha^{-1} whereas the lowest was observed with high yield site x control. At eight and 12 WAI, the highest pH was observed in the treatment that received high yield class x 750 kg dolomite ha^{-1} combination whereas lowest was noticed with low yield class x 0 $kgha^{-1}$.Ohno and Erich (1994) reported a constant pattern of rising to a peak pH value within the first 25 weeks after liming, and a decline in soil pH thereafter until a relatively constant pH was reach around 42 weeks. In the present study, soil pH rapidly increased within the first 12 weeks of incubation. Iljikic *et al.* (2011) and Meda *et al.* (2002) showed that liming with dolomite significantly influenced the soil pH while Kovacevic and Rastija, (2010) found that application of dolomite at 15 tha^{-1} raised pH (KCl) value by 2.62 units. Chang *et al.* (2003) reported that soil pH (H_2O) and pH ($CaCl_2$) values were greater in the limed plots than in the control by 0.1~0.6 units in pine plots after application of 1.5 t dolomite ha^{-1}.

Changes in soil EC (electrical conductivity)

The effect of dolomite on the soil EC during incubation is presented in Table 3.

Table 3. Effect of dolomite application and temporal variation of soil EC in different yield classes

Main Effect/Interaction	Soil EC(dSm^{-1})		
Yield class	4 weeks	8 weeks	12weeks
High	0.10	0.14	0.22[a]
Medium	0.10	0.13	0.23[a]
Low	0.08	0.12	0.16[b]
Significance	NS	NS	***
(Dolomite dosages $kgha^{-1}$)			
0	0.06[b]	0.10[c]	0.14[c]
250	0.08[ab]	0.12[bc]	0.19[b]
500	0.11[a]	0.14[ab]	0.21[b]
750	0.11[a]	0.16[a]	0.26[a]
Significance	**	***	***
(Interactions)			
High × 0	0.07	0.10	0.12[g]
High × 250	0.11	0.14	0.22[cd]
High × 500	0.12	0.15	0.24[bc]
High ×750	0.10	0.18	0.28[ab]
Medium × 0	0.06	0.11	0.18[def]
Medium × 250	0.08	0.12	0.19[cdef]
Medium × 500	0.12	0.13	0.23[bcd]
Medium × 750	0.14	0.14	0.30[a]
Low × 0	0.06	0.09	0.12[g]
Low × 250	0.07	0.12	0.14[fg]
Low × 500	0.09	0.13	0.17[efg]
Low × 750	0.12	0.17	0.21[cde]
Significance	NS	NS	*
CV %	27.7	18.6	10.5

Within a column, means followed by the same letter are not significantly different; *, **, *** significant at p=0.05, 0.01 and 0.001, respectively.

In the present study, the EC showed the significant difference (p<0.05) only at 12 WAI among high, medium and low yielding classes and the highest EC was recorded in the high yielding class. Soil EC was increased in each yield class with an increasing rate of dolomite throughout the incubation period. The EC shows the level of ability the soil water to carry an electrical current and is a good indication of the amount of nutrients available for crops to absorb.

Toure (1981) stated that liming increases EC and decreased the redox potential in acid sulfate soils. All dolomite dosages showed a significantly higher EC ($p<0.05$) compared with control and dolomite applied pots at 4, 8 and 12 WAI. The highest EC was recorded with application of 750 kg dolomite ha^{-1}. There were significant interactions ($p<0.05$) between the yield class and dolomite dosage only at 12WAI. The highest EC was observed with medium yield x 750 $kgha^{-1}$ interaction whereas the lowest EC was recorded with high yield x 0 kg dolomite ha^{-1}.

Changes in total soil nitrogen (N)

The total nitrogen in soil as influenced in relation to dolomite dosages and yield levels are shown in Table 4.

Table 4. Effect of dolomite application and temporal variation of total N in different yield classes

Main Effect/Interaction	Total soil N (%)		
Yield class	4 weeks	8 weeks	12 weeks
High	0.36^{a}	0.446^{a}	0.50^{a}
Medium	0.30^{b}	0.386^{b}	0.46^{b}
Low	0.29^{b}	0.378^{b}	0.46^{b}
Significance	***	**	**
(Dolomite dosages $kgha^{-1}$)			
0	0.13^{d}	0.11^{d}	0.11^{d}
250	0.22^{c}	0.36^{c}	0.46^{c}
500	0.37^{b}	0.48^{b}	0.58^{b}
750	0.55^{a}	0.68^{a}	0.76^{a}
Significance	***	***	***
(Interactions)			
High × 0	0.14^{gh}	0.12	0.10^{g}
High × 250	0.23^{f}	0.38	0.45^{f}
High × 500	0.42^{cd}	0.53	0.62^{d}
High ×750	0.64^{a}	0.76	0.84^{a}
Medium × 0	0.12^{h}	0.11	0.10^{g}
Medium × 250	0.21^{h}	0.33	0.44^{f}
Medium × 500	0.32^{e}	0.45	0.55^{e}
Medium × 750	0.54^{b}	0.64	0.75^{b}
Low × 0	0.11^{h}	0.10	0.13^{g}
Low × 250	0.22^{f}	0.35	0.49^{f}
Low × 500	0.37^{de}	0.44	0.56^{e}
Low × 750	0.48^{bc}	0.62	0.68^{c}
Significance	*	NS	***
CV %	13.2	11.3	6.2

Within a column, means followed by the same letter are not significantly different; *, **, *** significant at p=0.05, 0.01 and 0.001, respectively. NS=Not significant

Among the yield classes, total N showed a significant increase ($p<0.05$) throughout incubation period. The highest total soil N was recorded in the high yielding class at 4, 8 and 12 WAI while the lowest was recorded in the low yielding class. Results revealed that the total soil N significantly increased ($p<0.05$) in all dolomite dosages used, throughout incubation compared to the control. The highest total soil N was recorded in the 750 pots treated with kg dolomite ha^{-1} at all sampling stages.

Interactions were significantly different ($p<0.05$) only at 4 WAI and 12 WAI, but not at 8 WAI ($p>0.05$). The highest total N was observed with high yield class x 750 kg dolomite ha^{-1} at both 4 and 12 WAI. At 4 WAI, the lowest total soil N was recorded with low yield x 0 kg dolomite $ha^{-1}$and at 12 WAI with high yield x 0 kg dolomite ha^{-1}. Nyborg and Hoyt (1978) found that mineralization of organic N was doubled by liming for both virgin and cultivated soils. Badalucco *et al.* (1992) also stated that the microbial biomass C:N ratio decreased after liming thus, indicating that bacteria became predominant over fungi when soil acidity decreased. Fuentes *et al.* (2005) observed an increase in soil nitrate over time and in proportion to liming rate, suggesting that conditions were favorable for N-mineralization and nitrification.

Changes in available Phosphorus (P)

The data related to the available P as affected by different treatments are presented in Table 5.

Table 5. Effect of dolomite application and temporal variation of available P in different yield classes

Main Effect/Interaction	Available P ($mgkg^{-1}$)		
Yield class	4 weeks	8 weeks	12weeks
High	2.89^{c}	4.62^{c}	11.67^{c}
Medium	4.30^{b}	5.40^{b}	17.33^{b}
Low	5.12^{a}	6.11^{a}	20.67^{a}
Significance	***	***	***
(Dolomite dosages $kgha^{-1}$)			
0	3.62^{c}	4.67^{c}	11.44^{d}
250	3.94^{b}	5.29^{b}	14.00^{c}
500	4.21^{b}	5.66^{a}	17.56^{b}
750	4.64^{a}	5.89^{a}	23.22^{a}
Significance	***	***	***
(Interactions)			
High × 0	2.53	4.34^{d}	7.00
High × 250	2.73	4.53^{cdf}	8.00
High × 500	2.90	4.72^{cd}	13.33
High ×750	3.40	4.88^{c}	18.33
Medium × 0	4.03	4.68^{cd}	12.33
Medium × 250	4.19	5.51^{b}	15.00
Medium × 500	4.47	5.63^{b}	17.00
Medium × 750	4.53	4.59^{b}	25.00
Low × 0	4.31	5.00^{c}	15.00
Low × 250	4.91	5.82^{b}	19.00
Low × 500	5.27	6.64^{a}	22.33
Low × 750	5.98	6.99^{a}	26.33
Significance	NS	*	NS
CV %	7.0	15.4	10.4

Within a column, means followed by the same letter are not significantly different; *, **, *** significant at p=0.05, 0.01 and 0.001, respectively. NS=Not significant

Dolomite increased available P in all three yielding class throughout the incubation period. A higher available P was observed in low yielding class at each sampling while high yielding class recorded a low available P. The available P increased significantly ($p<0.05$)

with increasing dolomite rate throughout the incubation. High available P was observed in 750 kg dolomite ha^{-1} at 4, 8 and 12 WAI. There were significant interactions ($p<0.05$) between the yield class and dolomite dosage only at 8 WAI. The highest available P at 8 WAI was reported with low yield x 750 kg dolomite ha^{-1} whereas the lowest value of available P was observed with high yield x 0 kg dolomite ha^{-1}. Higgins *et al* (2012) observed that lime may enhance the mineralization of P or stimulate root growth. The plant available P after liming increased for the first 25 weeks and then declined with time at 9 gkg^{-1} application rate (Ohno and Erich, 1994). Liming also has improved nutritional status od maize and increased P concentration at 15 t dolomite ha^{-1} (Kovacevic and Rastija, 2010). According to Nduwumuremyi *et al.* (2013), soil available P decreased in the control treatments, while increased in plots that received lime at the rate of 1.4, 2.8 and 4.2 tha^{-1}.

Changes in Exchangeable Potassium (K)

Changes of exchangeable K throughout the incubation period in soil are presented in Table 6.

Table 4. Effect of dolomite application and temporal variation of exchangeable K in different yield classes.

Main Effect/Interaction	Exchangeable K ($mgkg^{-1}$)		
Yield class	4 weeks	8 weeks	12weeks
High	36.48a	43.67a	48.28 b
Medium	27.88 b	34.74 b	50.69a
Low	30.42 b	37.67 b	45.66 c
Significance	**	**	***
(Dolomite dosages $kgha^{-1}$)			
0	25.32 c	35.10 b	45.10 c
250	30.44 b	37.13 b	47.21 b
500	34.75ab	39.26 b	49.57a
750	35.87a	43.29a	50.95a
Significance	**	**	***
(Interactions)			
High × 0	33.64	40.67	45.76
High × 250	35.97	42.33	48.33
High × 500	36.78	44.67	48.72
High ×750	39.55	47.00	50.30
Medium × 0	18.67	29.39	46.94
Medium × 250	24.67	30.99	49.51
Medium × 500	34.13	34.91	52.07
Medium × 750	34.05	43.67	54.24
Low × 0	23.67	35.23	42.60
Low × 250	30.67	38.07	43.79
Low × 500	33.33	38.19	47.93
Low × 750	34.00	39.19	48.32
Significance	NS	NS	NS
CV %	16.3	12.4	13.7

Within a column, means followed by the same letter are not significantly different; *, **, *** significant at p=0.05, 0.01 and 0.001, respectively. NS=Not significant

Dolomite raised soil exchangeable K significantly in all tested dosages compared to the control throughout incubation. A higher exchangeable K was observed in 750 kg dolomite ha^{-1} at 4, 8 and 12 WAI. Ohno and Erich (1994) stated that plant availability of K increased for the first 25 weeks and then declined with time after applying 15 t of dolomite ha^{-1}. Statistical analyze revealed that the interaction of dolomite dosages and yield classes were not significant (p>0.05), which indicated that effects of dolomite dosages are independent over the different yield classes.

Changes in available Sulphur (S)

The available S as influenced by yield classes and dolomite dosages were given in Table 7. Dolomite decreased available S significantly in each low, medium and high yielding class at 4 WAI and 12 WAI. The results of the present study were in conformity with this statement.

Table 5. Effect of dolomite application and temporal variation of available S in different yield classes

Main Effect/Interaction	Soil available S ($mgkg^{-1}$)		
Yield class	4 weeks	8 weeks	12 weeks
High	5.72^{b}	3.92	3.64^{a}
Medium	5.22^{b}	3.95	2.60^{b}
Low	9.28^{a}	3.51	1.91^{c}
Significance	***	NS	***
(Dolomite dosages kg ha^{-1})			
0	4.45^{c}	2.95^{b}	1.22^{c}
250	5.76^{c}	3.75^{b}	1.67^{c}
500	7.46^{b}	5.02^{a}	3.43^{b}
750	9.30^{a}	3.46^{b}	4.56^{a}
Significance	***	*	***
(Interactions)			
High × 0	1.46^{e}	1.99^{d}	1.15^{d}
High × 250	3.73^{de}	4.91^{ab}	1.67^{d}
High × 500	8.19^{ab}	3.70^{bcd}	5.17^{b}
High ×750	9.51^{ab}	5.09^{ab}	6.56^{a}
Medium × 0	4.47^{d}	2.82^{cd}	1.17^{d}
Medium × 250	4.65^{cd}	3.85^{bcd}	1.25^{d}
Medium × 500	4.32^{de}	6.35^{a}	3.29^{c}
Medium × 750	7.45^{bc}	2.79^{cd}	4.71^{b}
Low × 0	7.41^{bc}	4.03^{bc}	1.33^{d}
Low × 250	8.90^{ab}	2.49^{cd}	2.08^{cd}
Low × 500	9.87^{ab}	5.00^{ab}	1.82^{d}
Low × 750	10.96^{a}	2.52^{cd}	2.42^{cd}
Significance	*	*	**
CV %	13.0	29.8	29.9

Within a column, means followed by the same letter are not significantly different; *, **, *** significant at p=0.05, 0.01 and 0.001, respectively. NS=Not significant

There was no significant difference (p>0.05) among the yielding classes at 8 WAI. The highest S at 4 WAI was observed in low yielding class and at 12 WAI in the high yielding class. Dolomite was caused to increase the microbial activities in the soil. Therefore, available S reduction may be due to the abundance of S utilizing bacteria in soil. Heydarnezhad *et al.* (2012) stated that S oxidation accomplished in both chemical and biological processes in the soil. Thiobacillus bacteria are the most important S-oxidizers in the soil. The main method of feeding the bacteria is chemiolithotrophic. The vital needed energy for their activities gain from the sulfur oxidation reaction. Consumption of S in the soil has reduced available S in soil. Results revealed that the interaction between yield classes and dolomite dosages was significant. The highest available S at 4 WAI was observed with low yielding class x 750 kg ha^{-1} dolomite interaction whereas lowest was observed with high yeld x 0 kg ha^{-1} interaction. At 8 weeks after incubation, the highest available S was observed in the treatment that received medium yield x 500 kg ha^{-1} dolomite interaction whereas lowest was recorded with high yield x 0 kg ha^{-1} interaction. At 12WAI, the highest available S was noticed with high yield x 750 kg ha^{-1} dolomite interaction whereas lowest was recorded in the treatment that received high yield x 0 kg ha^{-1} dolomite interaction.

Change in soil respiration

The CO_2 evolution during incubation influenced by two factors (yield classes and dolomite dosage) is shown in Table 8.

Table 6. Effect of dolomite application and temporal variation of soil respiration in different yield classes

Main Effect/Interaction	Soil Respiration(mg day^{-1})		
Yield class	4 weeks	8 weeks	12 weeks
High	3.89c	15.30	14.63^{c}
Medium	4.39b	17.08	16.15^{b}
Low	4.96a	17.31	25.69^{a}
Significance	***	NS	***
Dolomite dosages kgha^{-1})			
0	3.70c	12.44^{c}	12.64^{d}
250	4.13b	15.82^{b}	16.02^{c}
500	4.87a	17.87^{ab}	21.77^{b}
750	4.96a	20.12^{a}	24.85^{a}
Significance	***	***	***
(Interactions)			
High × 0	2.47^{f}	11.00^{de}	10.77^{e}
High × 250	3.09e	14.70^{cd}	14.67^{cde}
High × 500	4.78^{abc}	15.37^{c}	15.40^{cd}
High ×750	5.21^{a}	20.13^{ab}	17.67^{bc}
Medium × 0	3.87^{d}	9.44^{e}	11.70^{de}
Medium × 250	4.27^{cd}	15.78^{c}	15.80^{bcd}
Medium × 500	4.53^{bc}	20.32^{ab}	16.90^{bc}
Medium × 750	4.90^{abc}	22.79^{a}	20.20^{b}
Low × 0	4.75^{abc}	16.88^{bc}	15.47^{cd}
Low × 250	5.04^{ab}	17.00^{bc}	17.60^{bc}
Low × 500	5.29a	17.92^{bc}	33.01^{a}
Low × 750	4.77^{abc}	17.45^{bc}	36.68^{a}
Significance	***	**	***
CV %	8.8	14.9	14.3

Within a column, means followed by the same letter are not significantly different; *, **, *** significant at p=0.05, 0.01 and 0.001, respectively. NS=Not significant

Soil respiration (CO_2 evolution) was significantly increased ($p<0.05$) in each yield class at 4 and 12 WAI. There was no significant difference ($p>0.05$) among yield classes at 8 WAI. The highest soil respiration was recorded in the low yielding class at both 4 and 12 WAI. All dolomite dosages used showed a significantly higher soil respiration ($p<0.05$) throughout incubation period compared to the control. The highest soil respiration was observed in the treatment that received dolomite at the rate of 750 kgha^{-1}.

Results showed that there was significant interaction ($p<0.05$) between the two factors (yield class and dolomite dosage) at 4, 8 and 12 WAI. However, a higher CO_2 value at 4 WAI was recorded with low yield x 500 kg dolomite ha^{-1} interaction whereas the lowest was recorded with high yield x 0 kg dolomite ha^{-1}. At 8 WAI, a higher CO_2 value was noticed observed with the medium yield x 750 kg dolomite ha^{-1} interaction whereas the lowest was recorded with medium yield x 0 kg dolomite ha^{-1}. At 12 WAI, a higher CO_2 value was observed in the treatment combination low yield x 750 kg dolomite ha^{-1} whereas the lowest was recorded with high yield x 0 kg dolomite ha^{-1}.

Higgins *et al.* (2012) reported that liming drastically increase CO_2 evolution, respiration rates and microbial biomass carbon (MBC) than in non-limed soils, which could be due to the higher soil pH. Faster turnover rates and increased mineralization of organic matter were reported in lime-treated than in non-limed soils (Fuentes *et* al., 2006).

CONCLUSION

Liming considerably affected the soil nutrient availability and soil respiration. Application of dolomite made soil pH, soil EC, total N, available P, exchangeable K, and soil respiration in sufficient or higher levels except that of S. Available S was significantly decreased during incubation. The optimum dolomite level out of tested rates was 750 kgha^{-1}.

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