黄色酸性土壌における石灰施用がキビの収量と養分吸収に及ぼす効果(生産環境学科)

Effect of Liming on the Yield and Nutrient Uptake of Common Millet Grown on a Yellow Acid Soil of Okinawa

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Keywords : Common millet, Yellow acid soil, liming, soil pH, nutrient uptake
キーワード：キビ、黄色酸性土壌、石灰施用、土壌pH、養分吸収

Summary

Common millet (*Panicum miliaceaum var.*) was grown during September to November, 1994 in 1/5000a Wagner pots containing 3.0kg yellow acid soil collected from the central part of Okinawa Island. It was aimed to study the improvement of growth,yield and nutrient uptake of millet and soil chemical properties by liming. Calcium carbonate was applied to the soil at 4 levels, viz. A(0g), B(7.5g),C(15.0g) and D(22.5g/pot), of which treatments raised the soil pH to 4.4, 5.1, 6.4, and 6.8, respectively.

In the control treatment, no plant survied indicating that the millet can not tolerate strong acidity. The highest grain yield, weight of aerial parts and roots were obtained from the C treatment followed by the B treatment. Consequently soil pH about 6 was deemed to be best for the millet.

The plant analysis showed that N, P and K accumulated higher at the grand growth stage before heading than the mature stage. Ca and Mg concentrations increased in the plant up to the mature stage. Increase or decrease in Si concentration of the plant varied by the treatment. Before heading, N and Si concentrations of the plant were highest on the C treatment but others were highest on the D treatment. About the quantity of nutrients taken up in the aerial portion of the millet, N was not different among the treatments, Si was highest in the B, K and Mg were in the C, and P and Ca were in the D treatment.

The analysis of the soil after growing millet showed that enrichment of Ca by liming but exhaustion of N, Mg, and K by the cropping. Also indicated were remain of fertilized P, and increase in CEC by liming and cropping.

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Intorduction

Liming, as the term applies to agriculture, is the addition to the soil of calcium or calcium and magnesium containing compound that is capable of reducing acidity. The improvement of soil reaction with liming would aid in the conversion of certain plant nutrients to available forms[4]. Liming also improves the soil physical condition for proper plant growth and plays an improtant role in the soil fertility. Effect of calcium carbonate on the growth performance of crops in acid soils are reported elsewhere[5,6]. Common milet, a gramineous srop is widely distributed in the world as a food crop of man and livestock. It is also grown on some of the remote islands of Okinawa as their specialty crop in recent years. But the information on growing common millet in acid soils with lime appilcation is limited.

THe present study was undertaken:(a) To study the growth and yield response of common millet to liming in a Yellow acid soil, and (b) to determine the influence of liming on the nutrient uptake of common millet and on soil chemical properties.

Materials and Methods

1. Soil

The surface soil (0−20cm) of a Yellow soil was collected for the experiment from a hilly area of old alluvium of Ishikawa city at the central part of Okinawa Island. The profile of the soil collection site was simply described in Table 1. The soil was sieved through a wire screen with 1cm openings and used for the pot experiment. An aliquot of the soil was sieved through a wire screen of 2 mm openings after air-drying and used for the determination of neutralization buffer capacity and chemical properties, that was shown in Table 2.

Table 1. The profile of the soil collected

Horizon	Depth (cm)	pH	Moist color		Texture
A	0～16	5.0	7.5YR5/5	Dull brown	SiC
AB	16～30	4.5	10YR6/6	Bright yellowish brown	SiC
B	30～50	4.7	10YR7/6	Bright yellowish brown	HC
C	50<	4.2	10YR6/8	Bright yellowish brown	HC

Table 2. Chemical properties of the soil used for the experiment

pH		CEC	Exch. bases (me/100g)				Base satu.	Total N	Avail. P_2O_5
(H_2O)	(KCl)	(me/100g)	Ca	Mg	K	Na	(%)	(%)	(mg/100g)
4.22	3.54	6.51	1.46	0.37	1.58	0.24	56.1	0.08	0.64

2. Liming treatment

Lime($CaCO_3$) was applied to raise soil pH at 4 levels with about equal intervals from a neutralization buffer curve viz. 0.0, 7,5, 15.0 and 22.5 g lime/pot in this experiment, where the Wagner pot of 1/5000a was used to contain 3kg of soil each. These treatments were replicated 3 times and denoted as $A_{1,2,3}$, $B_{1,2,3}$, $C_{1,2,3}$, and $D_{1,2,3}$, respectively. After mixing lime with the soil,750 ml water was added to each pot and the pots were kept standing for 3 deys to reach equilibrium. Then, chemical fertilizer (B 13−17−10) was mixed with the soil at rate of 10.5 g/pot. Soil samples were collected from separately treated pots 3 days after liming(3DAL) to determine changes of pH.

3. Pot cultivation of millet

Twenty seeds of common millet(*Panicum mileasceum var.*),of which seeds were obtained from Shiraho Village of Ishigaki Island, were sown to each pot on September 10, 1994. The pots were arranged in a way of randomization in the greenhouse. After germination, thinning was practiced twice and finally three plants were kept per pot. Water was given to the level of moisture equivalent of the soil as needed. Plant samples from the 2nd thinning before heading was used for determining nutrient contents. The millet were harveseted through the last week of November, 1994. The aerial portions (stem, leaves and unfilled panicles) were determined for dry matter and analyzed for nutrient contents. The roots were collected and determined for air-dry weght. Soil samples were also collected after harvesting millet and analyzed for chemical properties.

4. Chemical analysis of soil and plant

Chemical analysis of the soil and plant samples were done according to common methods described elsewhere[2,3].

Soil pH was determined with a glass electrode pH meter at a soil:solution ratio of 1:2.5. Cation exchange capacicty(CEC) of the soil was determined by ammonium acetate method and exchangeable bases were measured in an acetate leachate with an atomic absorptoin unit. Total nitrogen was determined by Kieldahl procedure. Available phosphate was extracted with 0.002 N H_2SO_4 and determined by the molybdenum blue method with a spectrophotometer.

The plant samples were solubilized by wet ashing method. Nitrogen with ascorbic acid addition and P with vanadomolydenum were measured by a spectrophotometre. Ca, Mg and K were measured by atomic absorption unit. Si were determined gravimetrically on the residue.

Results and Discussion

1. Effect of liming on soil pH

The soil pH as affected by the liming treatment was determined for original soil, 3 days after liming (before planting) and after harvesting common millet, and shown in Fig. 1.

Before planting, the highest pH of 6.82 was attained by the application of 22.5 g/pot lime followed by 15.0 and 7.5 g/pot, respectively. The lowest pH (4.38) was from the untreated soil as a matter of cause. The pH of the soils decreased by 0.28 to 1.19 unit due to the

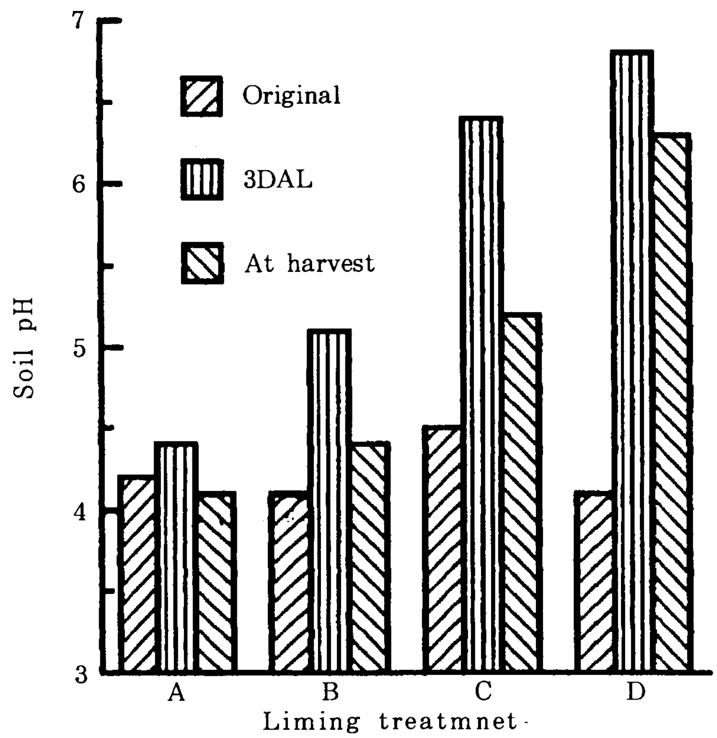

Fig.1. Effect of liming on soil pH before and affer growing common millet

millet cultivation. The decrease in soil pH was possibly due to the decrsase of Ca in soil solution as absorbed by the millet plant and the lowering effect of lime application with time passed. However, after harvesting millet, the pH of the soil trerted with lime was still higher by 0.31 to 2.2 unit than the non-treated soil. The liming treatments that added calcium nutrient and caused a rise of soil pH gave remarkable effects on the growth performanace of the millet in the tested soil as discussed later. This higher soil pH may give beneficial residual effects on the growth and yield of successive millet crop, if it is planted again.

2. Effect of liming on the yield and yield parameters of millet

The grain yield (air-dry), and weights of roots(air-dry) and aerial portion (oven-dry stems+leaves+unfilled panicles) of the common millet per pot were shown in Fig.2.

The non-limed soil gave no grain yield, where the plant grew only up to very infant stage but could not survive further from strong acidity of the soil. The maximum grain yield of 27.48 g/pot was obtained from the C treatment(pH 6.4) followed by the B treatment(pH 5.1) and the D treatment (pH 6.8). The difference in the grain yield was little between the C and B treatments, but significant between the B and D treatments.

The weight of roots (air-dry) and aerial portion (oven-dry) showed the same tendency for the grain yield. About the weight of aerial portion, unfilled panicles occupied more in the C and D treatments than in the B treatment.

The number of panicle ranged from 8 to 30/pot, though the number of tiller was not determined. The highest number of panicle was observed in the D treatment, in which false grain was highest.

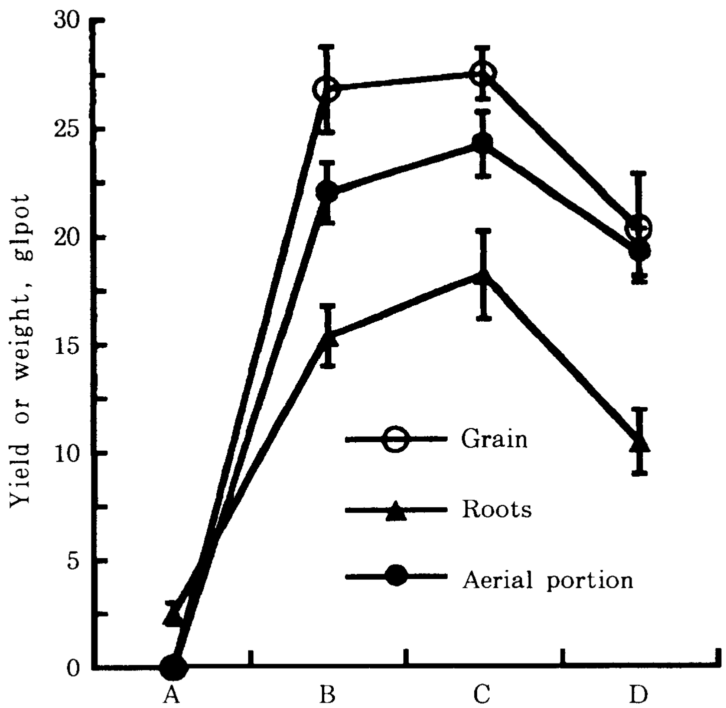

Fig.2. Effect of liming on grain yield and weight of roots and aerial portion of common millet (Small bar is standard deviation of 3 replicates.)

From the above, it was deemed that liming is very essential to grow millet on this kind of acid soil and that it is most preferable to maintain soil pH at the range from 5.1 to 6.4 for the soil and the millet variety tested here. This pH range agrees somehow with Brady[1] who illustrated that millet crops grow well in the range of pH from a little bellow 5 to about 7.

3. Effect of liming on the nutrient content and uptake of millet

The nutrient contents(%) of the millet determined at two growth stages, namely defore heading and at maturity, were shown in Table 3, where also shown were the quantities of nutrients taken up by the crop per pot that were calculated from the aerial dry matter and nutrient concentration.

According to Table 3, P_2O_5 (0.88 to 0.98%), K_2O (2.55 to 3.02%), CaO (0.19 to 0.39%), and MgO (0.31 to 0.44%) increased in the concentartion with the rise of soil pH by lime application (pH 5.1 in the B,6.4 in the C, and 6.8 in the D treatments) at the grand growth stage before heading, while nitrogen (3.31 to 4.19%) and silica (0.81 to 1.7%) were highest in the C treatment (pH 6.4). These results were the indication of preferable effects of liming on helping the plant to absorb nutrients probably best at around pH 6.4. The preferable effects in nutrient absorption of plant caused by liming in acid soils were being reported elsewhere[4,5,6].

The highest nitrogen content (4.19%) in the young plant on the C treatment showed a positive correlation with the grain yield, the dry matter of aerial portion and weight of roots. While the highest nitrogen (1.1%) in the matured stage on the D treatment might have lead to delay of maturity of the crop that ultimately reduced the grain yield owing to

Table 3. Concentration and uptake of nutrients of common millet as affected by liming in a Yellow acid soil*

Treatment	N			P_2O_5			K_2O		
	% before heading	% at harvest	Uptake at harvest (g/pot)	% before heading	% at harvest	Uptake at harvest (g/pot)	% befor heading	% at harvest	Uptake at harvest (g/pot)
B	3.28±0.14	0.98±0.23	0.21±0.05	0.88±0.09	0.28±0.07	0.06±0.02	2.55±0.03	2.50±0.12	0.55±0.02
C	4.19±0.17	0.85±0.08	0.21±0.03	0.91±0.07	0.25±0.02	0.06±0.01	2.83±0.04	2.51±0.24	0.61±0.04
D	3.31±0.37	1.10±0.17	0.21±0.03	0.98±0.01	0.45±0.06	0.10±0.01	3.02±0.36	2.07±0.11	0.40±0.04
Treatment	CaO			MgO			SiO_2		
	% before heading	% at harvest	Uptake at harvest (g/pot)	% before heading	% at harvest	Uptake at harvest (g/pot)	% before heading	% at harvest	Uptake at harvest (g/pot)
B	0.19±0.01	0.49±0.01	0.11±0.01	0.31±0.03	1.79±0.07	0.39±0.04	1.30±0.27	1.25±0.03	0.28±0.02
C	0.26±0.01	0.53±0.01	0.13±0.01	0.40±0.03	2.37±0.22	0.57±0.02	1.70±0.14	0.95±0.06	0.23±0.02
D	0.39±0.06	0.73±0.03	0.14±0.01	0.44±0.07	2.52±0.03	0.48±0.03	0.81±0.05	1.36±0.04	0.26±0.02

*Figures are the means and stadard deriations of 3 replicates.

more false grain than the other treatments.

About the nutrient concentartions at maturity of the crop as compared with the grand growth stage before heading, nitrogen, potassium and phosphorus decreased with the increase in the plant biomass, but calcium and magnesium were kept increased. An increase and decrease in the concentration of silica were observed by the treatment. These figures indicated that nitrogen, phosphorus and potassium accumulated in the young plant, but the accumlation of calcium and magnesium occurred toward the crop's maturity. Silica accumulated higher in the young plant on the C treatment, but higher at maturity on the D taeatment.

The quantity of nutrients taken up(g/pot) in the aerial portion of the matured crop was in the order of K_2O(0.4 to 0.61g), MgO(0.39 to 0.57 g), SiO_2(0.23 to 0.28g), N(0.21 g), CaO(0.11 to 0.14 g) and P_2O_5(0.06 to 0.10 g). Among the treatments, nitorgen was not different, but silica was highest in the B treatment, potassium and magnesium were in the C treatment, and phosphorus and calcium were in the D treatment.

4. Effects of liming and growing millet on soil chemical properties

Soil chemical properties as nutrient status determined after growing the millet crop were shown in Table 4.

Table 4. Chemical properties of the soil after growing common millet*

Taeatment	pH		CEC	Exch. bases(me/100g)				Base satu.	Tatal N	Avail. P_2O_5
	(H_2O)	(KCl)	(me/100g)	Ca	Mg	K	Na	(%)	(%)	(me/100g)
A	4.12	3.36	6.68	1.77	0.59	2.36	0.42	74	0.13	20.7
B	4.43	3.66	7.38	5.50	0.26	1.37	0.64	100	0.09	13.0
C	5.16	4.36	14.65	9.67	0.11	1.28	0.66	83	0.09	14.0
D	6.32	5.69	15.23	13.80	0.14	1.12	0.49	103	0.10	18.3

*Figures are the means of 3 replicates.

The every treatment received same amount of chemical fertilizer (10.5 g of BB13−17−10/pot). The crop did not grow on the non−limed A treatment soil, so the chemical properties of that soil were the good reference to compare with the other treatment soils.

The soils decreased in pH by growing millet as discussed before (Fig.1). The CEC of the A taeatment soil was 6.68 me/100 g , but it increased up to 15.23 at maximun by liming and cropping. It is known that the rise of soil pH caused by liming results in increase of negative charge of clay minerals in acid soil[7]. The increase of the soil CEC in the B, C, and D treatments were also contaibuted by the leftover fine root fragments that were not possible to remove for the weight measurement of roots and also probably by root exudate.

Exchangeable calcium in the limed soils showed much increase as affected by liming in spite of the uptake by the millet. Magnesium and potassium decreased below original level (Table 2) by the cropping. Nitrogen also decreased near the original level by growing millet. The level of phosphorus decreased from the fertilized level (A treatment) by the cropping, but it was still higher than the original level. This would reasonably be regarded as the indication of leftover from the applied fertilizer. Moreover, phosphorus was brought available by higher rise of pH on the D treatmnet.

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黄色酸性土壌における石灰施用がキビの収量と養分吸収に及ぼす効果

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要 約

地域特産品としてキビ（*Panicum miliaceaum var.*）の栽培が離島で広がりつつある。今回は酸性土壌におけるキビ栽培に資するため、酸性土壌における石灰施用がキビの収量、養分吸収及び土壌の理化学性に及ぼす効果を調べた。

沖縄島中部から採取した黄色酸性土壌に炭カルを４水準で施用して土壌pHを変え、その３Kgづつを5,000分の１アールワグネルポットに詰めてキビを栽培した。ポット当たりの炭カルは０g（Ａ区）、7.5g（Ｂ区）、15g（Ｃ区）、22.5g（Ｄ区）で３反復とした。炭カル施用３日後の土壌pHはそれぞれ4.4、5.1、6.4、6.8となった。これに化学肥料（BB 13−17−10)をポット当たり10.5gづつ施用して、キビを播種した。栽培はガラス室で行い、キビのポット当たり株数は最終的に３株とした。栽培期間は1994年９月上旬〜11月下旬であった。

炭カル無施用のＡ区ではキビは数cmまで伸びたもののそれ以降は消失してしまい、キビの耐酸性は非常に弱いことが示された。キビの穀粒収量、地上部乾物重、根の風乾量などはＣ区、Ｂ区、Ｄ区の順で高かったが、Ｃ区とＢ区の差は小さく、B区とD区の差は大きかった。これよりキビの生育に対する好適土壌反応はpH６前後であると考えられた。

出穂前に間引きした若い植物体と収穫時の成熟植物体の分析では、窒素、リン酸、カリ等の含量は前者で高く、カルシウム、マグネシウムは後者で高くなる傾向が認められ、ケイ酸は処理区により傾向がばらついた。若い植物体では窒素とケイ酸はＣ区で、他の養分はＤ区で最も高かった。成熟時における養分吸収量は窒素は処理区間で差が無かったが、ケイ酸はＢ区で、カリとマグネシウムはＣ区で、リン酸とカルシウムはＤ区で最も多かった。

キビ収穫後の土壌では、炭カル施用によるカルシウムの著しい増加が認められたが、窒素、マグネシウム、カリ等の含量は施肥前の原土並みまたはそれ以下に低下した。リン酸は施肥前よりかなり多く、施肥による富化が伺えた。CEC は増加しており、これは炭カル施用に伴うpH上昇の効果と残留細根による効果と考えられた。

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