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BUCKWHEAT GROWTH, LEAF MINERAL CONTENTS AND SOIL CHEMICAL PROPERTIES AS AFFECTED BY BURNING WITH LOW FIRE INTENSITY IN SHIFTING CULTIVATION AT KYUSHU MOUNTAINS, JAPAN

Tomohiro Kondo

Graduate School of Agriculture, Kyoto University, Kyoto, Japan

Corresponding e-mail: kondo.tomohiro.0z@kyoto-u.ac.jp

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ABSTRACT

Shifting cultivation with low fire intensity is widely practiced in Kyushu mountains, Japan. For investigating the effects of low intensity burning on chemical properties of soils, samples from the burned and unburned area of a field in Shiiba Village in Kyushu mountains were collected and analyzed. The growth and leaf mineral contents in buckwheat grown in burned and unburned areas were also measured. Results indicated that soil pH, available P, exchangeable K and Mg in the soil increased, though inorganic N was not affected by the burning. The plant growth was enhanced due to burning. However, only leaf P content was increased by the burning though leaf K and Mg contents were not changed. The effect of increased soil pH on buckwheat growth was unclear. Even the low intensity burning increased available P and increased the growth of buckwheat in Kyushu mountains under shifting cultivation.

Keywords: Available P, exchangeable base, *Fagopyrum esculentum*, slash and burn cultivation, soil pH

Introduction

In Kyushu mountains the area of shifting cultivation was about 2,500 ha in 1950's (Sasaki 1970), where buckwheat (*Fagopyrum esculentum*), Japanese millet (*Echinochloa esculenta*), foxtail millet (*Setaria italica*), adzuki bean (*Vigna angularis*), soyabean (*Glycine max*) and rice bean (*V. umbellata*) were cultivated in mixed or/and rotation cropping (Kondo and Koga 2021). The timing of burning was depended on the first crop grown after burning, e.g. for buckwheat cultivation the timing of burning was summer, while for millets it was in spring. At Shiiba Village of the Miyazaki Prefecture located at the northern part of Kyushu mountains, burning is still practiced in shifting cultivation at the early August for buckwheat cultivation. The precipitation in June, July, and August of that area is generally high, e.g. in Shiiba Village the average precipitations were 588, 570, and 333 mm in June, July, and August, respectively (Japan Metrological Agency 2021). Burning during high precipitation period might be unique in Kyushu mountains, though the timing of burning is generally during or at the end of dry season for fully combustion.

The low fire intensity during burning in shifting cultivation in Shiiba Village was often reported, which was probably due to high soil water content caused by precipitation during June and July. According to Kamata *et al*. (1987) after 30 minutes of burning the litter often remained unburned where soil temperature at 2.5 cm depth was not increased, though at spot, where litter was burned completely, the soil maximum temperature at 2.5 cm depth was 53 °C in Shiiba Village. Shiiba and Utsumi (2010) also reported that litter often remained unburn at shifting cultivation in Shiiba Village. At the shifting cultivation field burned on August 3, 2019, in Shiiba Village, it was also observed that duration of burning was about one hour and the litter on the soil often remained unburn where soil temperature did not increase. Two-hour after the ignition the temperature of ash surface on the soil was about 60 °C. On the other hands, soil maximum temperature at 2-3 cm depth were 100-200 °C in Thailand (Tanaka *et al*. 2001), 150-250 °C in Zambia (Ando *et al*. 2014), 43-139 °C in Sarawak, Malaysia (Kendawang *et al*. 2004). In general, due to burning soil pH and mineral contents such as P, K, Ca, Mg are increased by the ash applied to soil, inorganic N is released from organic matter, and consequently the crop growth is enhanced. However, the effects of burning with such low fire intensity in Kyushu mountains on crop growth are unclear. Therefore, the present study was initiated to determine the effects of burning on buckwheat

growth in shifting cultivation field at Shiiba Village, where fire intensity was low.

Materials and Methods

On August 3, 2017, the field at Shiiba Village in Kyushu mountains (131.0 °E, 32.5 °N) was burned. Burned organic matter was mainly bamboo and the amount was about 60 Mg/ha. Due to rainfall of the day before the burning, some areas were burned, while some were not. Even in burned area, litter on the soil surface often remained unburned. Buckwheat, a local variety of Shiiba Villege, was sown two-hour after the ignition, and the flowering period was from the end of September to the end of October. On August 2 and 3, before and just after burning, soils were collected at the depth of 0-10 cm, and on October 1, soils from burned and unburned fields were collected at the depth of 0-10 and 0-2 cm. The soils were collected from the upper, middle and lower part of the slope and mixed well to make one composite sample. The composite samples were made 5 times horizontally along the slope. The soil sample was air-dried to pass through a 2 mm mesh sieve. Soil pH (H_2O) was measured with a soil to water ratio of 1:5. Total C and N content of the soil were analyzed by the dry combustion method with a NC analyzer (Sumigraph NC-220F, Sumika Chemical Analysis Service, Ltd, Japan). NH_4-N was extracted with 2 M KCl and determined with indophenol method (Keeney and Nelson, 1982). NO_3-N was extracted with water and determined with Cataldo method (Cataldo *et al*., 1975). Exchangeable K, Ca, and Mg were extracted with 1 M CH_3COONH_4 solution at pH 7.0 and determined by atomic absorption spectrophotometry (AA-6200, Shimadzu, Japan). Available P was determined following Bray II method (Bray and Kurtz, 1945).

On October 1, plant height, stem diameter, number of branches, nodes of main stem and nodes with flower of buckwheat grown with and without burning were measured. Relative leaf chlorophyll content (SPAD value) of seventh leaf from the top was also measured using a chlorophyll-meter (SPAD-502, Konica Minolta Sensing, Inc., Japan). Leaf N, P, K, Ca, and Mg contents were measured using the same method as Kondo *et al*. (2020). Replication number for measuring those parameters was 11.

The data were analyzed using t-test. The significance level was adjudged at $p < 0.05$.

Results

Soil pH was increased by burning (Table 1). However, NH_4-N was decreased just after burning, and two-month after burning NO_3-N was decreased at the depth of 0-2 cm, though at the 0-10 cm inorganic N was not affected. Total N and C contents were not affected by the burning. Exchangeable Ca and Mg at the depth of 0-10 cm were not affected, though Mg was increased at the depth of 0-2 cm two months after burning. Exchangeable K at the depth of 0-10 cm was increased only just after burning, and that at the depth of 0-2 cm was increased by the burning even two-month after burning. Available P was increased by the burning process.

Table 1. Effect of burning on soil properties in shifting cultivation at Shiiba Village, Japan, in 2017

	Sampling Date	Depth (cm)	pH	NH_3-N (mg N/kg)	NH_4-N (mg N/kg)	Total C (%)	Total N (%)	Ex-Ca ($cmoL_c$	Ex-Mg ($cmoL_c$	Ex-K ($cmoL_c$/kg)	Available P (mg P/kg)
Before burning	Aug. 2	0-10	4-87	23.2	102.6	17.9	1.2	0.7	0.3	0.3	23.6
After burning	Aug. 3	0-10	5.02	33.5	68.8	19.6	1.4	1.8	0.5	1.1	35.5
			*	ns	**	ns	ns	ns	ns	*	*
Unburned	Oct. 1	0-10	4.70	49.4	141.4	17.3	1.2	0.3	0.3	0.5	29.7
Burned	Oct. 1	0-10	5.17	36.7	186.3	17.0	1.2	0.6	1.0	1.4	47.4
			*	ns	**	ns	ns	ns	ns	ns	*
Unburned	Oct. 1	0-2	4.60	39.8	114.3	21.0	1.5	1.4	0.5	0.7	60.5
Burned	Oct. 1	0-2	5.21	20.4	113.1	19.8	1.4	39.1	1.8	1.5	89.1
			**	*	ns	ns	ns	ns	*	**	*

**, * and NS indicate significant differences at P<0.01, P<0.05, and not significant, respectively by T-test (n=5).

Table 2. Effect of burning on buckwheat growth in shifting cultivation at Shiiba Village, Japan, in 2017

	Plant height (cm)	Stem diameter (mm)	Number of branches	Number of main stem nodes	Number of nodes with flower
Unburned	70.3	5.9	7.6	11.0	36.3
Burned	98.8	7.9	13.4	12.6	70.4
	**	**	*	*	**

**, and * indicate significant differences at P<0.01, P<0.05, respectively by t-test (n=11).

Table 3. Effect of burning on leaf mineral contents and SPAD value of buckwheat in shifting cultivation at Shiiba Village, Japan, in 2017

	Leaf mineral contents (%)					SPAD value
	N	P	K	Ca	Mg	
Unburned	3.10	0.12	1.83	1.44	0.30	45.3
Burned	3.12	0.27	2.20	1.10	0.33	42.5
	ns	**	ns	ns	NS	ns

**, and ns indicate significant differences at P<0.01, and not significant, respectively by t-test (n=11).

Plant height, stem diameter, and number of branches, nodes of the stem and nodes with flower were increased by the burning (Table 2). SPAD value was not affected by the burning. Leaf P was increased by the burning, though N, K, Ca, and Mg were not changed much (Table 3).

Discussion

In the experiment, litter on the soil remained unburned due to rainfall of the day before the burning, and so the fire intensity had been low, though temperature of the soil was not measured. By burning with such low fire intensity, the buckwheat growth was enhanced due to increasing available P. Available P was also increased by burning in the studies of Juo and Manu (1996) and Thomaz *et al*. (2014). On the other hand, inorganic N and leaf N content were not increased by the burning. NH_4-N is a direct product of the burning, while NO_3-N forms from NH_4-N some weeks or months after the burning (Covington and Sackett 1992). Increased release of NH_4-N caused by soil heating based on increase in fire intensity was found in Zambia (Ando *et al*. 2014), semiarid America (Johnson *et al*. 2011), and Southeast Asia (Tanaka *et al*. 2001). One of the main sources of NH_4-N release is the mortality of microbes, but microbe can live under low fire intensity such as 100 °C at 2.5 cm depth (Neary *et al*. 1999). Soil temperature at the depth of 2.5 cm in the experiment might had been lower than 100 °C, judging from unburned litter on soil surface, and then NH_4-N was not increased by burning. Exchangeable K and Mg of the soil were increased slightly, but leaf K and Mg contents were not changed much. Thus, the increasing exchangeable base presumably did not enhance buckwheat growth. Soil pH was increased, but its effect on buckwheat growth was unclear.

Based on the findings of this study it may be concluded that available P, and exchangeable K and Mg in soil were increased by low fire intensity, though inorganic N and exchangeable Ca were not, and the growth of buckwheat was enhanced due to increasing available P.

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