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Effects of an Agropastoral System on Soybean Production

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1. Introduction

Increase of the cereal production in the world is desired for increase of global food demand. The savanna agro-ecosystems of South America are one of the most important potential areas for expansion of agricultural production in the world. Therefore, the opening of some 12 million ha of this area has been conducted over the last 40 years (Kerridge, 2001). For example, in the Brazilian savanna, grain crops cover 12-14 million ha and introduced pasture area is over 50 million ha (Maceado, 2001).

However, under continuous cropping, soil productivity declines due to soil loss, soil compaction, loss of organic matter and increase in pests, diseases and weeds. For example, the soybean yield in Yguazu, Alto Parana, Paraguay, increased to over 3 t/ha after the introduction of a no-tillage cultivation system in 1983. However, the yield increase stopped in the early 1990's, and recently the yield seems to be decreasing (Seki, 1999; Shimoda et al., 2010). As a means to solve these problems, Kerridge (2001) suggested that integrated agropastoral systems with no-tillage appeared to be the key to sustainable development. But, since the period used as pasture and the pasture manegement methods have various combination in the system, few studies have been evaluated them synthetically.

The Japan International Research Center for Agricultural Socience Japan (JIRCAS) was conducted the joint reserchs of agropastoral system with the National Beef Cattle Research Center of the Brazilian Agricultural research Corporation (EMBRAPA-CNPGC) from 1996 to 2006 and many results were obtained from several experiments (Macedo et al., 2004; Kanno et al., 2004; Miranda et al., 2004 etc.). In addition, JIRCAS was conducted with the Japan International Cooperation Agency's Paraguay Agricultural Technology Center (CETAPAR-JICA) from 2003 to 2008 (Shimoda et al., 2010; 2011). In this report, I clarify the positive effects of an agropastoral system synthetically.

2. Material and methods

2.1 Study site

Two experiments (Exp.-1 and Exp.-2) were conducted in CETAPAR-JICA for soybean productivity with agropastoral system. CETAPAR-JICA is located in Colonia Yguazu (a Japanese settlement, 35°27'S, 55°04'W) in Alto Parana, Paraguay. Soil in this area is fertile and is known as "Terras Roxas" in Brazil (Igarashi 1997). Mean annual temperature and precipitation from 1972 to 2002 were 21.6°C and 1545 mm, respectively.

2.2 Experimental design

For Exp.-1, part of a field at CETAPAR-JICA, where soybean and wheat had been continuously cropped in a no-tillage system since 1993, was converted to Guinea grass (*Panicum maximum* cv. Tanzania) pasture in 1996. Established as a permanent pasture, it was maintained without fertilizer, cutting, or renovation for 7 years after establishment, and was used as a complementary pasture. In October 2003, the pasture was converted into an agropastoral plot where soybean and wheat were cultivated. the agropastoral plot was 2.97ha. In another part of the field adjacent to the agropastoral site, where soybean and wheat had been continuously cultivated in a no-tillage system since 1993, the non-converted treatment was replicated in three plots (control plots). Each plot was 0.68 ha.

For Exp.-2, 15 plots were arranged at the study site, each plot was 0.68 ha (124 m × 55 m) where soybean and wheat had been continuously cultivated in a no-tillage system since 1993. Twelve plots were randomly converted to Guinea grass (*Panicum maximum* cv. Monbasa) pasture in November 2003. These pastures were managed as intensive grazing pastures under high grazing pressure. The strip grazing was conducted in the pasture year round, and cattle were fed supplement during four months in dry season. Fertilization was also conducted (ammonium sulfate). The stocking rate was from 4.5 to 6.0 UA/ha for 3 years. Three plots of these pastures were also reconverted to soybean-wheat fields in October 2007 as no-tillage system (agropastoral plots). The non-converted treatment was replicated in three plots (control plots). Control plots in Exp.-1 and Exp.-2 were same plots.

2.3 Chemical and physical properties of soil

To investigate the chemical properties of the soil, samples from depths of 0-10, 10-20, 20-40, and 40-60 cm were collected independently from each plot, and the concentrations of phosphate, the percentage organic matter and pH, were measured. The concentrations of phosphate were analyzed using the Mehlich-III method, and percentage organic matter was analyzed using the Walkley-Black method. The pH of soils was measured using a pH meter (Horiba Co. Ltd.).

Moreover, soil was sampled from 0–5, 5–10, 10–20, 20–40, and 40–60 cm depths for measurement of physical properties, three phases of soil, bulk density, and soil aggregates (Only Exp.-1). Three phases of soils and soil aggregates were measured using a three-phase meter and an aggregate analyzer (Daiki Rika Kogyo Co., Ltd.), respectively.

We analyzed soybean and wheat production and soil chemical and physical data between the agropastoral plots and control plots using t-test, and the annual variation of chemical data in both plots using the Tukey-Kramer method. Details of the study methods were shown in Shimoda et al (2010, 2011).

3. Results

3.1 Soybean production

Since the yield of a soybean had a large change every year, the effect of agropastoral system was evaluated by using ratio of the soybean yield in agropastoral plots to that in control plots (Table 1). As a result, the ratios of the first year when reconverted into soybean field from the pasture were 2.35 in Exp-1 and 1.02 in Exp-2, respectively. In addition, the ratios of the second year were 1.86 in Exp-1 and 1.42 in Exp-2, respectively. The effect of Exp-1 was larger than that of Exp-2.

The first, second and third year in Exp.-1 were drought years and the second year in Exp.-2 was drought year too. The ratios of drought years were larger than the ratio of normal year in both experiments.

Moreover, during the experimental period in Exp.-1, the relative yield of soybean decreased year by year from 2.31 t/ha in the first year to 1.11 t/ha in the fourth year.

Pasture condition	Experiment 1 (Exp-1)[1]	Experiment 2 (Exp-2)[2]
Period as a soybean field before rotation	More than 3 years	More than 10 years
Period as a pasture after rotation	7 years	4 years
Introduced grass species	*P. maxmum* cv. Tanzania	*P. maxmum* cv. Monbasa
Grazing intensity	Extensive	Intensive
Weght gain per hectare	Little(unknown)	1.34ton/ha
Soybean production (Agropastoral/continuous cropping)		
First year soybean production after rerotation	1.48ton/ha (2.35 times)*	3.71ton/ha (1.02 times)
Second year soybean production after rerotation	3.56ton/ha (1.86 times)*	1.24ton/ha (1.42 times)*
Third year soybean production after rerotation	2.84ton/ha (1.45 times)*	-
Forth year soybean production after rerotation	2.74ton/ha (1.11 times)	-

Source: [1] from Shimoda et.al. (2010) and [2] from Shimoda et al. (2011).
*:Drought year.

Table 1. Study site profile and soybean production

3.2 Chemical properties

In Exp-1, the soil organic matter content in the agropastoral plots was 1.20 times higher than that in the control plots with significant difference at the reconversion from the pasture. However, in Exp-2, the soil organic matter content in the agropastoral plots was same (1.04 times) as that in the control plots. Under intensive grazing (Exp.2), even if soybean field was converted to the pasture, the accumulation of organic matter was not promoted (Fig. 1).

On the other hand, the phosphate concentration in agropastoral plots was 0.28 times than that in the control plots in Exp.-1 and 0.19 times than that in the control plots in Exp.-2 (Tble 2). Under extensive and intensive grazing, the accumulation of phosphate at soil surface was dissolved. After conversion to the pasture, phospate concentration was reduced by half in only two years (Fig. 2). But, phosphate accumulation was promoted in control plots. In addition, pH of soil surface was also increased with dissolution of phspate accumulation, the acidic soil was improved by nutral soil (Fig. 3).

Chemical properties	Experiment 1 (Exp-1)[1] 7rd year pasture/Control plot	Experiment 2 (Exp-2)[2] 3rd year pasture/Control plot
Organic matter	1.20 times***	1.04 times
Phosphate	0.28 times***	0.19 times**

Source: [1] from Shimoda et.al. (2010) and [2] from Shimoda et al. (2011).
**:P<0.01. **:P<0.001

Table 2. Comparison of soil chemical properties at soil surface (0-10cm in depth)
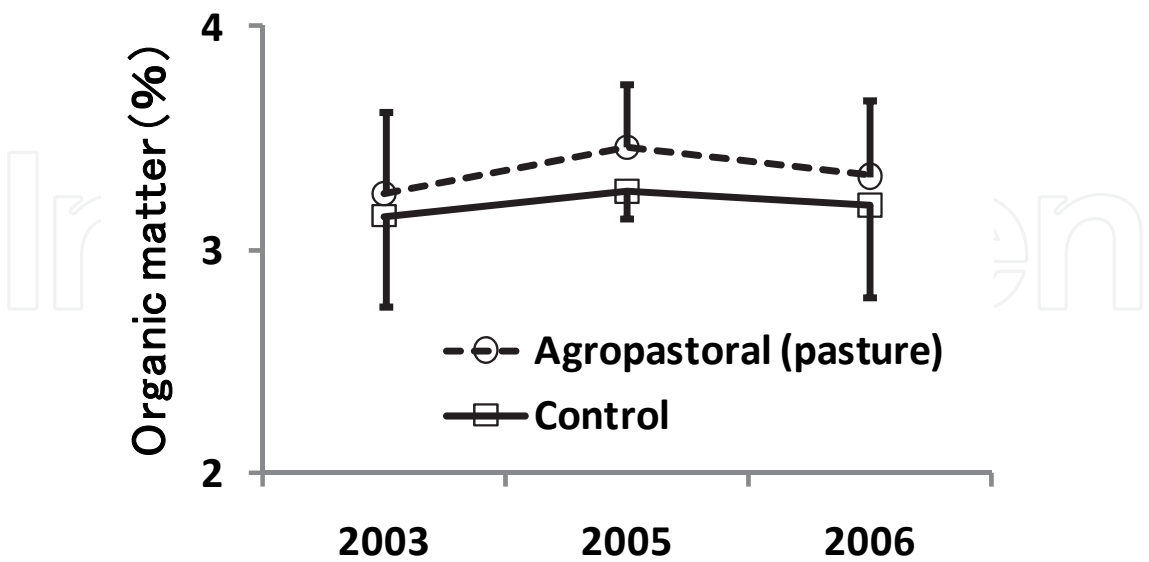
Fig. 1. Change in organic matter percentage (%) of Exp.-2 in the soil surface (0-10cm at depth).
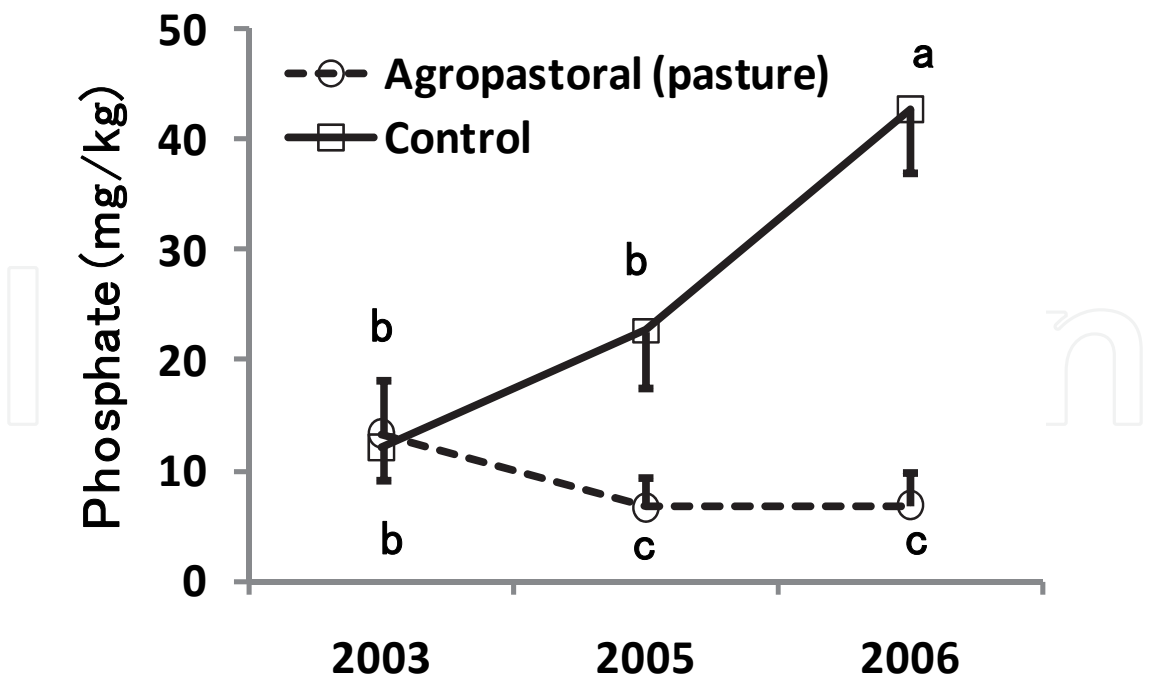

Fig. 2. Change in phosphate concentration (mg/kg) of Exp.-2 in the soil surface (0-10cm at depth). A different letter is significantly different.
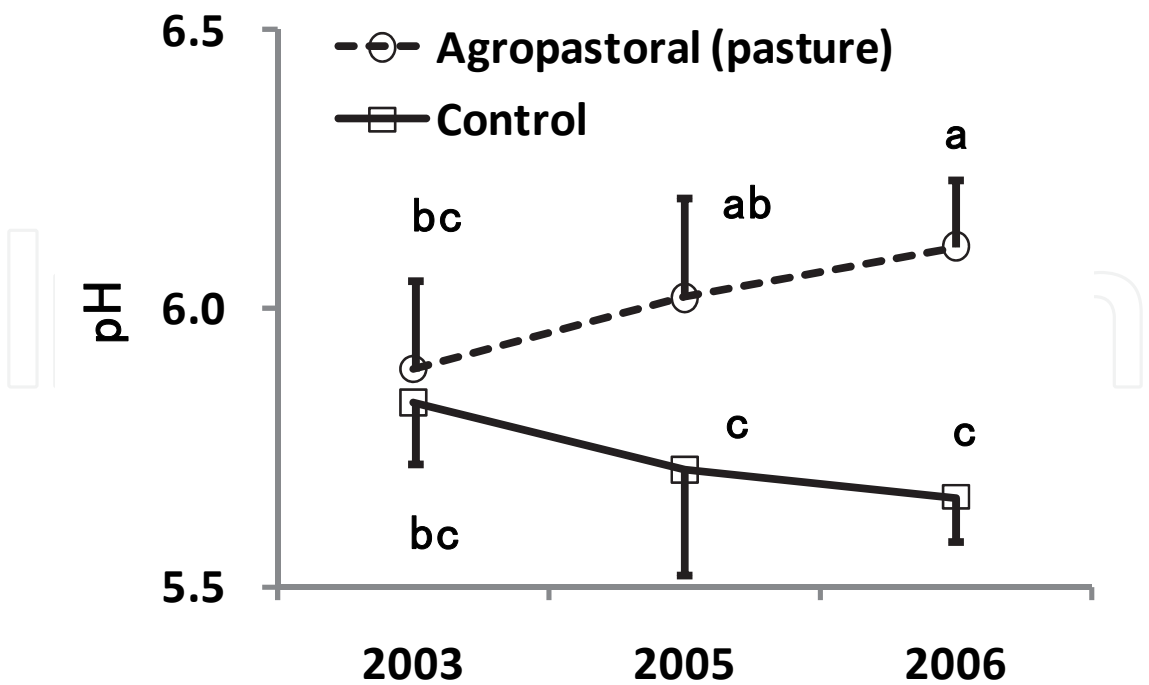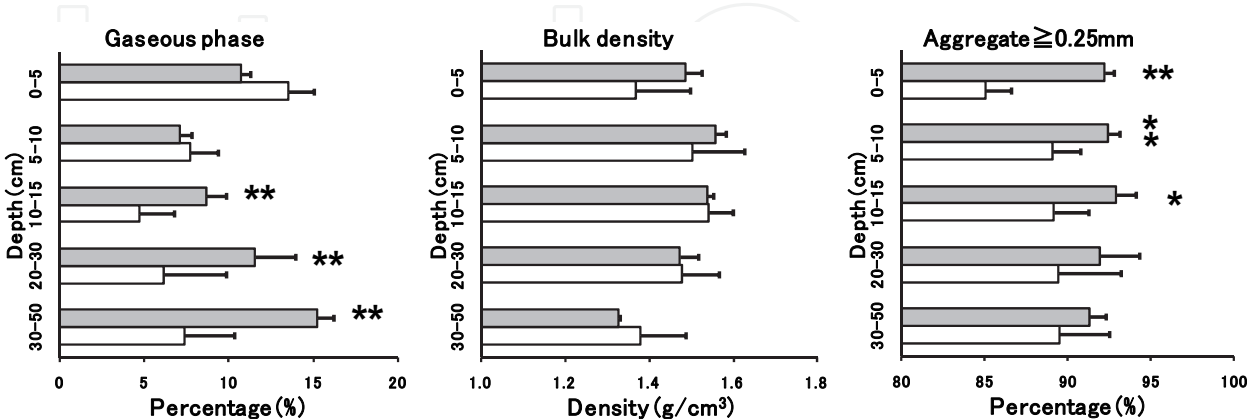
Fig. 3. Change in pH of Exp.-2 in the soil surface (0-10cm at depth).
A different letter is significantly different.

3.3 Physical properties

In soil samples from deeper than 10 cm, the gaseous phase percentage in the agropastoral plots was significantly higher than in control plots (Fig 4), but was lower at the soil surface (0–10 cm depth). The bulk density of samples from the soil surface of agropastoral plots was higher than that of control plots, and the bulk density of soil samples from deeper than 20 cm was lower than that of control plots (Fig. 4). But, they did not have significantly difference. In addition, the percentage of large aggregates in the soil of the agropastoral plots was 3 to 7% higher than that in control plots at each depth (Fig. 4). Especially, at the soil surface, it was significantly higher than that in control plots.

*,**:Data are significantly different at 5% and 1% level from the control plot, respectively.

Fig. 4. Physical properties of the soil in agropastoral and control plots of Exp.-1.
Gray bar is the mean value and SD in agropastoral plot and white bar is those in control plot.

4. Discussion

In the first and second year after reconversion from the pastures, the ratio of the soybean yield in agropastoral plots to that in control plots in Exp.-1 was higher than that in Exp.-2. Therefore, it was thought that the positive effects on soybean productivity of the agropastoral system with extensive grazing and long term pasture was higher than that with intensive grazing and short term pasture. Macedo et al. (2004) reported that the mean ratio of the soybean yield in the first year between all 4 years agropastoral plots and control plots was 1.12 (calculated from their table) under a conventional grazing system which the weight gain of cattle per hectare was one-third that of our intensive grazing system. But, it had higher grazing pressure than that of our extensive grazing system. Therefore, it was considered that the positive effect on soybean productivity was large as the grazing pressure was low.

However, it was thought that it would be lost in about four years even if agropastoral system with the extensive grazing and long term pasture (seven years) was conducted. So, it was important for this system to convert a field into a pasture continually.

In the drought year, the positive effect on soybean productivity was clear. It was considered as a reason that the phosphate accumulation at soil surface was dissolved. Many studies reported that the root of soybean was distributed within a shallow soil layer with no-tillage system (Iijima et al., 2007; Izumi et al., 2009). In addition, the phosphate accumulates near the soil surface, which restricts a crop root distribution within a shallow soil layer with a no-tillage system (Holanda et al., 1998; Seki et al., 2001). Plants with shallower root systems have a disadvantage for uptake and sensitive to drought (Schwinning ,1988).

In general, soybean does not grow well in acidic soil, and a pH range of 6.0 to 6.5 is best for soybean cultivation (Kokubun, 2002). In our system, soil pH in top soil improved from 5.89 to 6.11 over 3 years in the pasture, and conversely, soil pH became lower and the soil acidified in the control plots. Therefore, possibly the improvement of soil pH had same effect on the increase of the soybean yield.

Studies have reported that the accumulation of organic matter in soil is promoted by introducing agropastoral systems (Miranda et al., 2004; Salton & Lamas, 2007; Shimoda et al., 2010). In general, organic matter develops the soil aggregate structure and improves the water-holding capacity (Uwasawa, 2002). However, the accumulation of organic matter was promoted in Exp.-1 and not promoted in Exp.-2. Ogawa & Mitamura (1982) also reported that the accumulation of organic matter was not promoted by grazing. It was a reason that the root growth was inhibited by cutting the aboveground part of the grass (Davidson & Milthorpe, 1966a; 1966b). In addition, a lot of grass was grazed and much cattle meat (1.54 ton/ha) was carried out from the pasture every year under our intensive grazing. Therefore, it was thought that the positive effects on soybean productivity in Exp.-1 was larger than that in Exp.-2 by the promotion of organic matter accumulation.

In Exp.-1, at soil surface (0-10 cm at depth) in agro-pastoral plots, the percentage of gaseous was lower and bulk density was higher. Soil compaction of soil surface inhibits soybean production (Ae, 1997). However, since soil sampling was carried out immediately after killing off Guinea grass by herbicide, soil compaction at the surface would disappear rapidly by decomposition of the root of Guinea grass after that. And, since the percentage of gaseous phase of soil in agropastoral plots was higher in the soil layer from 10 cm to 50 cm at depth, it was thought that soil compaction occurred in no-tillage cultivation had improved. In addition, percentage of large aggregate of soil of agro-pastoral plots was

higher than that of control plots in each depth. Higher percentage of large aggregate may promote inflow of air to underground. Inflow of air to underground promotes nitrogen fixation of soybean (Ae 1997). Therefore, it seemed that the improvement of physical properties of soil has contributed to recovery of soybean productivity.

5. Conclusion

The effects on soybean productivity of the agropastoral system with extensive grazing and long term pasture and with intensive grazing and short term pasture were positive. In addition, the positive effect on soybean productivity was clear in the drought year. It was thought the positive effects were promoted by the dissolvation of phosphate accumulates near the soil surface, accumulation of organic matter, improvement of soil compaction, and etc..

The investigation which took in intensive grazing was carried out for the income compensation of soybean farmers during the period used as a pasture. However, it was thought that productivity recovery of a soybean and the productivity of livestock had a relation of a trade-off. So, it waits for research to shorten the period used as a pasture.
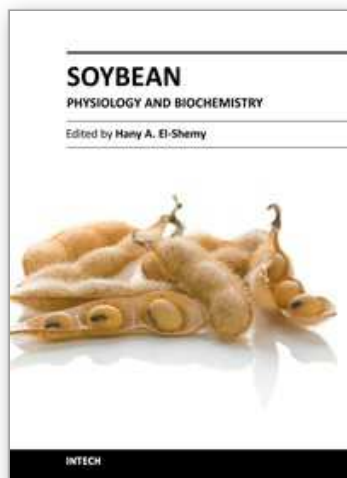
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Soybean Physiology and Biochemistry

Edited by Prof. Hany El-Shemy

Worldwide, soybean seed proteins represent a major source of amino acids for human and animal nutrition. Soybean seeds are an important and economical source of protein in the diet of many developed and developing countries. Soy is a complete protein and soyfoods are rich in vitamins and minerals.Soybean protein provides all the essential amino acids in the amounts needed for human health. Recent research suggests that soy may also lower risk of prostate, colon and breast cancers as well as osteoporosis and other bone health problems and alleviate hot flashes associated with menopause. This volume is expected to be useful for student, researchers and public who are interested in soybean.

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