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Farming System and Management

Morio Matsuzaki
National Agricultural Reseach Center (NARC),
National Agriculture and Food Research Organization (NARO)
Japan

1. Introduction

In the cultivation of soybean, it is necessary to pay attention to nitrogen absorption and soil organism. Nitrogen of 11 - 31kg (an average of 16 kg) is necessary to produce soybean grains of 200 kg (Salvagiotti et al., 2008) because soybean has high grain protein content. Soybean and rhizobia (*Bradyrhizobium japonicum*) form symbiosis for N2 fixation (Gray & Smith, 2005). Soybean N2 fixation is approximately half of the soybean nitrogen uptake (Salvagiotti et al., 2008), and soybean absorbs the other half from fertilizer or soil. If there is much inorganic nitrogen in soil, the N2 fixation is suppressed (Ray et al., 2006), and the amount of fertilizer application for soybean is a little. Therefore, soybean yield probably depends on the quantity of soil organic nitrogen which is mineralized during crops growing period. This means nitrogen which a soil microbe holds, and it is called "biomass nitrogen" (Jenkinson & Parry, 1989).

Soybean is influenced by a biologic factor. Soybean forms symbiosis not only rhizobia but also arbuscular mycorrhizal (AM) fungi (Antunes et al., 2006; Troeh & Loynachan, 2003). The biologic factors such as nematodes, soil-borne diseases become the problem in soybean. In continuous cropping of soybean, soybean cyst nematode (SCN : *Heterodera glycines*) reduce soybean yield approximately 30% (Donald et al., 2006). Sudden death syndrome (SDS) due to the coinfection of SCN and *Fusarium solani* becomes the problem in U.S.A. (Rupe et al., 1997; Xing & Westphal, 2009).

Soybean secretes flavonoids such as daidzein or genistein, and they are key signal compounds for control of symbiosis with rhizobia and AM fungi (Antunes et al., 2006). Glycinoeclepin which kidney beans (*Phaseolus vulgaris*) secrete promotes the hatching of the SCN (Kushida et al., 2002). Crops influence soil organism by various compounds to secrete from root (Faure et al., 2009). Therefore, the growth and yield of soybean are probably influenced by the preceding crop. In soybean, yield decrease is remarkable by continuous cropping (Matsuda et al., 1980; Matsuguchi & Nitta, 1988).

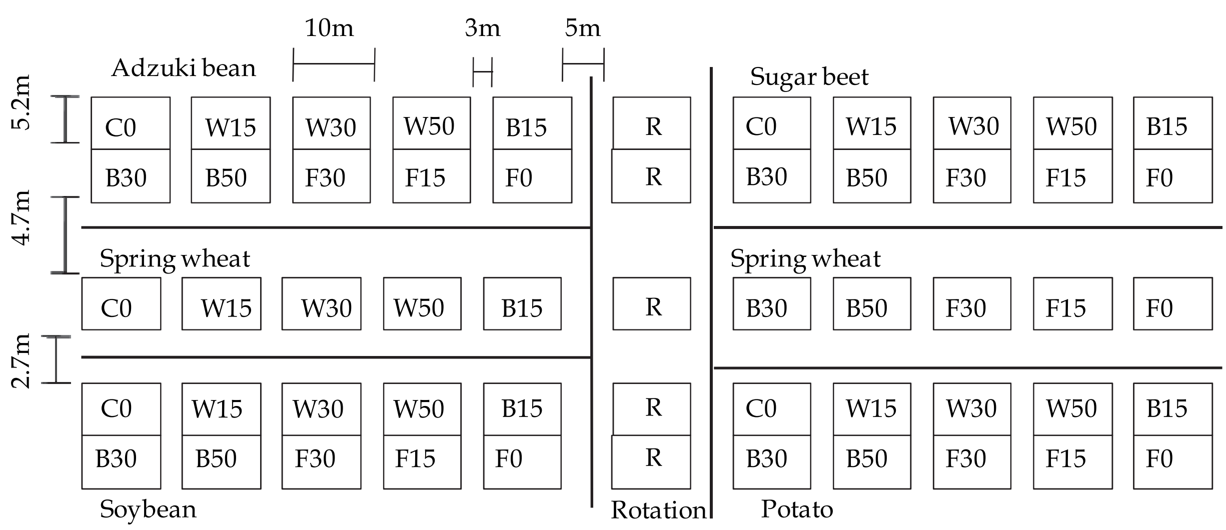
The continuous cropping experiment with five crops including soybean was conducted in northern Japanese Hokkaido for 16 years (Memuro continuous cropping experiment). Organic matter application and soil fumigation were conducted in the experiment. Soybean continuous cropping will influence soil microbe (Kageyama et al., 1982; Matsuguchi & Nitta, 1988). Soil biomass nitrogen increases by organic matter application (Sakamoto & Oba, 1993). Soil fumigation promotes mineralization of soil nitrogen and suppresses nitrification

(Neve et al., 2004). Soil fumigation sterilizes Fungus (Asano et al., 1983) and nematodes. This experiment is a good example to study the influence of the soil microbe on soybean. About a subject picked up in this experiment, the knowledge of past were surveyed.

	C0	W15	W30	W50	B15	B30	B50	F30	F15	F0	R
Continuous cropping	○	○	○	○	○	○	○	○	○	○	
Rotation											○
Wheat straw manure		15	30	50				30	15		
Burk compost					15	30	50				
Soil fumigation								○	○	○	

* The application rate of organic matter is expressed in t/ha.
Soil fumigation (D-D) was applied from 1990 to 1995.

Table 1. Treatments in Memuro continuous cropping experiments.



The cropping sequence of rotation plot is sugar beet – Potato - Adzuki bean - Spring wheat - Soybean ·

Fig. 1. The treatment plots in Memuro continuous cropping experiment.

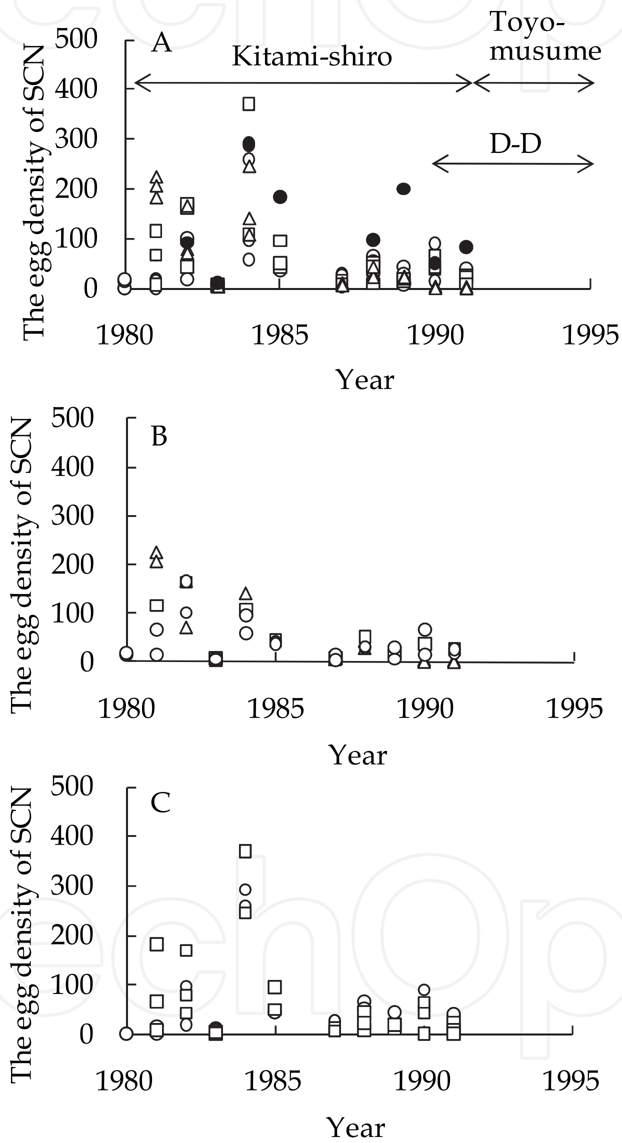
2. Memuro continuous cropping experiment

2.1 Eexperimental design

Memuro continuous cropping experiment (42°53' N, 143°04' E) was conducted from 1980 to 1995. Soybean (*Glycine max*), adzuki bean (*Vigna angralis*), sugar beet (*Beta valgaris*), potato (*Solanum tuberosum*) and spring wheat (*Triticum aestivum*) were cultivated in the experiments. The eleven plots were established in each crop (Fig. 1). One plot was rotation plot, and other plots were continuous cropping plots (Table 1). Soybean was cultivated only chemical fertilizer in rotation plot (R) and the control plot in continuous cropping plots (C0). Wheat straw manure was applied in every year from 1980 at 15, 30, 50 t/ha, respectively (W15, W30, W50). Burk compost was applied in every year from 1981 at 15, 30, 50 t/ha, respectively (B15, B30, B50). D-D (1,3-dichloropropene) was applied from 1990 as a soil fumigation. In the soil fumigation plots, wheat straw manure was applied in every year from 1980 at 0, 15,30t/ha (F0, F15, F30).

2.2 The effect of continuous cropping to soybean cyst nematode (SCN)

The time course changes of egg density of SCN were showed in Fig. 2A. Closed symbols showed the value of rotation plot, and open symbols showed that of continuous cropping plots. The nematode susceptibility cultivar "Kitami-shiro" was used from 1980 to 1991, and nematode-resistant cultivar "Toyo-musume" was used from 1992. D-D was applied from 1990. In the continuous cropping plots, the egg density of SCN tended to decrease from 1985. Thereafter, the egg density in the rotation plot was higher than that in the continuous cropping plots.



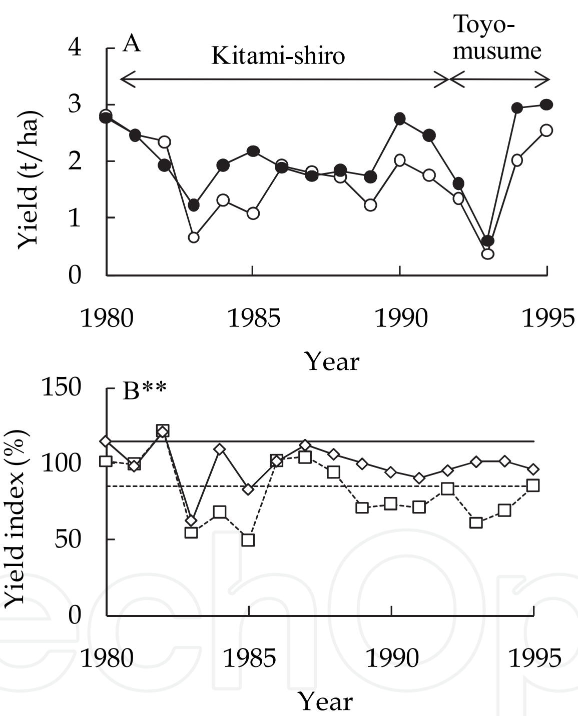
○ : C0, M15, M30, M50, □ : B15, B30, B50, △ : F0, F15, F30, ● : R.
Graph A: The changes of all plots.
Graph B: The changes of plots in which the egg density peaked at 1981.
Graph C: The changes of plots in which the egg density peaked at 1984.
The unit of the egg density of SCN is number / g dry soil.

Fig. 2. The time course changes of egg density of SCN.

■: plots in graph B, □: plots in graph C.

Fig. 3. The placement of soybean continuous cropping plots in Graph B and C.

Fig. 2B and 2C show the time course changes of egg density of SCN in the continuous cropping plots. Fig. 2B shows the plots which the egg density of SCN was highest in 1981-1982. Fig. 2C shows the plots which the egg density of SCN was highest in 1984. The placement of each plots are showed in Fig. 3. The closed squares show the plots in Fig. 2B, and the open squares show the plots in Fig. 2C. The plots which belonged in Fig. 2B were located in the south side of experiment field, and the plots which belonged in Fig. 2C were located in the north side. The difference of time course changes of egg density probably depended on the position of plots. In both plots, the egg density of SCN decreased by 2 - 5 years continuous cropping.



Graph A: The changes in yield of C0 and R.
○ : C0, ● : R.
Graph B: The time course changes in yield index.
□ : C0 / R × 100.
◇ : The means of (W15, W30 W50, B15, B30 or B50) / R × 100,
Solid line: the value of ◇ in 1980.
Dotted line: solid line - least significant difference from Stutentized range.
** is significantly in 1%.

Fig. 4. The time course changes of yield and yield index of soybean.

2.3 The effects of treatments to soybean yield

2.3.1 Time course change

Soybean yield was measured from 1980 to 1995. The time course changes of yield of R and C0 plots were showed in Fig. 4A. In Hokkaido, soybean yield decrease by cool summer damage. It was a cool summer in 1983 and 1993, and soybean yield decreased. To examine the effects of continuous cropping and organic matter application, analysis of variance (ANOVA) was conducted for the soybean yield data. First, the yield of continuous cropping plots except soil fumigation plots (C0, W15, W30, W50, B15, B30, B50) were converted into the index by the yield of rotation plot (R). For the index of the continuous cropping + organic matter application plots (W15, W30, W50, B15, B30, B50), ANOVA was conducted as treatment replication (Fig. 4B). The solid line is a value of 1980, and the dotted line is solid line - least significant difference. In the year when index significantly decreased than that of 1980, soybean yield probably decreased by continuous cropping. For reference, the indexes of C0 were shown.

The mean of indexes of organic matter application plots did not decrease significantly except 1983. However, the indexes of C0 of 1983~1985 were lower than a dotted line. This time was almost coincided with the time when the egg density of SCN increased. The indexes of C0 increased again afterwards. The egg density of SCN decreased, too. Therefore, it is suggested that the yield decrease of continuous cropping was influenced by SCN. The organic matter application probably increased soybean yield.

2.3.2 Treatment effects

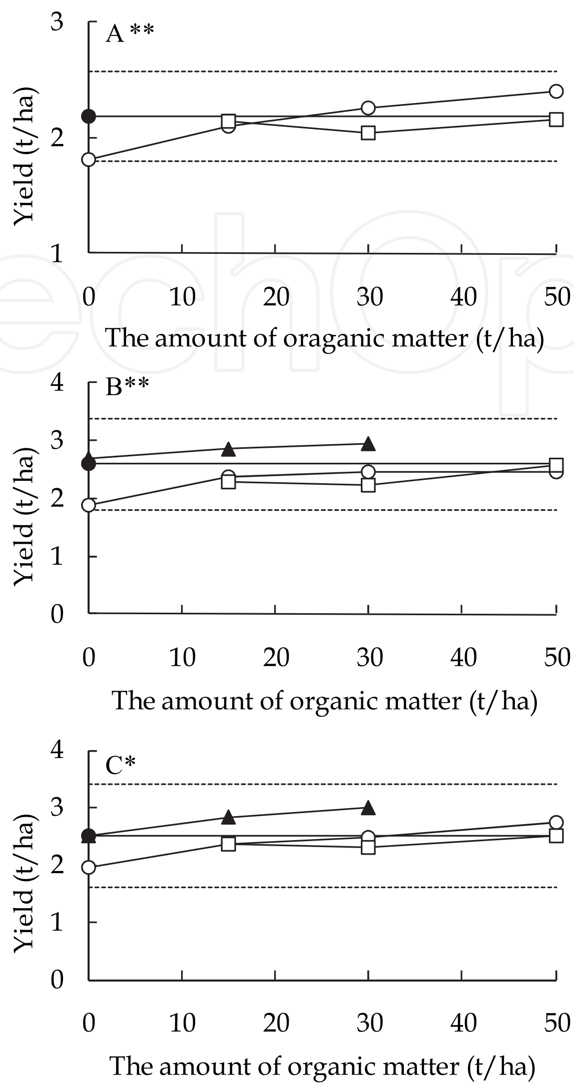
For the soybean yield data, ANOVA was conducted as year replication. Using a yield of all plots except soil fumigation plots (C0, W15, W30, W50, B15, B30, B50, R) of 1981~1995, the effects of continuous cropping and organic matter application were investigated. Using a yield of all plots in 1990~1991, the effects of continuous cropping, organic matter application and D-D on nematode susceptibility cultivar "Kitami-shiro" were investigated. Using a yield of all plots in 1992~1995, the effects of continuous cropping, organic matter application and D-D on nematode resistant cultivar "Toyo-musume" were investigated.

By ANOVA for the data of 1981-1995, yield decreased significantly by continuous cropping, and the decrease was approximately 20% (Fig. 5A). Organic matter application increased yield. By ANOVA for soil fumigation period (Fig. 5B, 5C), yield did not decrease significantly by continuous cropping. However, the trend in Fig. 5A was similar in those figures. Yield decreased by continuous cropping, and increased by organic matter application. By D-D, yield increased at the same level as the rotation plot. D-D might remove the effect of continuous cropping as a nematocide. However, the egg density of SCN declined before D-D application period. The effect of D-D was found to "Toyo-musume" that was nematode resistant variety. Therefore, it was suggested that D-D influenced the factor except SCN.

3. Factors to influence continuous cropping soybean

3.1 Soybean cyst nematode (SCN)

SCN forms the cyst containing a large number of eggs (Ichinohe, 1955a). Two or three generations of SCN can grow up in the soybean growing period of Hokkaido (Ichinohe, 1955a). SCN inhibits rhizobial adherence, too (Ichinohe 1955a). The damage of SCN is most remarkable if SCN invaded to soybean at 2-3 weeks after sowing (Okada, 1968). The damage of SCN is reduced by fertilization (Okada, 1966). SCN reduces the growth of soybean, but



○ : C0, M15, M30, M50, □ : B15, B30, B50, ▲ : F0, F15, F30, ● : R.
Graph A : ANOVA for 1981 – 1995 (All period of continuous cropping),
Graph B : ANOVA for 1990 – 1991 (D-D for "Kitami-shiro"),
Graph C : ANOVA for 1992 – 1995 (D-D for "Toyo-musume").
Solid line : the value of R,
Dotted lines : solid line ± l.s.d. from Studentized range.
** is significantly in 1%, * is 5%.

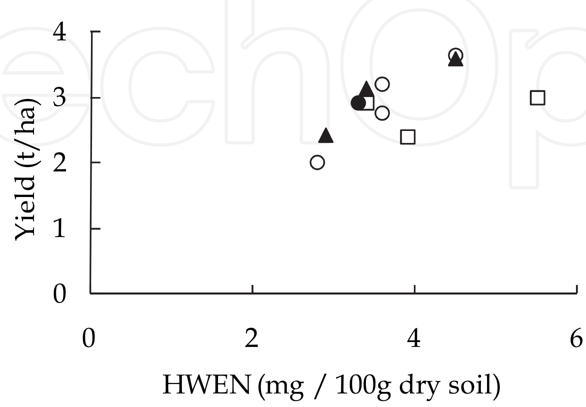
Fig. 5. The treatment effects to soybean yield.

SCN cannot increase with poor growth soybean (Ichinohe, 1955b). Therefore, if the soybean growth is less, the density of SCN may be less. In Memuro continuous cropping experiment, the egg density of SCN was low in the cool summer damage year (1983).
Soil fumigation, organic matter application and cultivation of non-host crops or the resistant variety is effective for control of SCN. D-D etc are used for soil fumigation. Organic acid or ammonia released from organic matter suppresses a nematode (Oka, 2010). By organic matter including the chitinous substance, chitinase activity in the soil rises, and a nematode is suppressed (Akttar & Malik, 2000; Oka, 2010). Brassicaceae crops including glucosinolates

release isothiocyanates, and suppress a nematode (Oka, 2010). Probably Marigold suppresses a nematode by α- terthienyl (Oka, 2010).
Host crops of SCN is soybean, adzuki bean and kidney bean (Ichinohe, 1953). SCN is not parasitic on a non-leguminous crop. SCN is parasitic on other leguminous crops, but cannot become the adult (Ichinohe, 1953). After five years cultivation of corn (*Zea mays*) which is non-host crop, SCN increases by soybean cultivation (Porter et al., 2001). By the planting of the single resistant variety, the races adapted to the resistant variety increased (Shimizu & Mitsui, 1985). In contrast, the leguminous crop red clover (*Trifolium pratense*) may be used as trap crop (Kushida et al., 2002). Red clover hatch the egg of SCN, but the hatched larva cannot become the adult (Kushida et al., 2002). Therefore, after red clover cultivation, the density of SCN decreased (Kushida et al., 2002).
In Memuro continuous cropping experiment, SCN density decreased by 5 years continuous cropping of soybean. In other experiments, the density of SCN decreased by continuous cropping, too (Hashimoto et al., 1988). This phenomenon is called "SCN decline". SCN decreases in wheat-soybean double cropping (Bernard et al., 1996). It is suggested that these phenomena are caused because fungus or bacteria are parasitic on SCN. *Hirsutella* is parasitic on the second larva of SCN (Liu & Chen, 2000). *Fusarium* and *Verticillium* are parasitic on a female, cyst and egg of SCN (Bernerd et al., 1996; Sayre, 1986, Siddiqui & Mahmood, 1996). The nematode control using these microorganisms is possible. However, in Memuro continuous cropping experiment, soybean might be cropped continuously before the experiment station establishment. Long term continuous cropping may be needed to "SCN decline".

3.2 Nitrogen supply and soybean yield

In American Corn Belt, the potential yield of soybean is estimated at 6 - 8t/ha (Salvagiotti et al., 2008). Because soybean is crop which is high grain protein content, soybean need a large quantity of nitrogen. Nitrogen of 106 – 310 kg N / ha is necessary to get a yield of 2 t / ha (Salvagiotti et al., 2008). In the Tokachi district, the fixed nitrogen of soybean is 4 – 127 kg N /ha (Nishimune et al., 1983). There is negative correlation between amount of applied fertilizer and N2 fixation (Salvagiotti et al., 2008). Fertilizer nitrogen for soybean is less than 40kgN/ha. Therefore, soybean needs to absorb nitrogen from soil. Soybean yield will increase with soil nitrogen absorption.



○ : C0, M15, M30, M50, □ : B15, B30, B50, ▲ : F0, F15, F30, ● : R.

Fig. 6. The relationship of the hot water extractable nitrogen (HWEN) of postharvest soil and soybean yield (1994).

Soil Nitrogen can be divided into inorganic, humus and biomass nitrogen (Jenkinson & Parry, 1989). Crops absorb inorganic nitrogen. The available nitrogen is organic nitrogen at sowing, but it is mineralized during a growing period. It is suggested that most of available nitrogen come from biomass nitrogen (Sakamoto & Oba, 1993). Organic matter application increases biomass nitrogen (Sakamoto & Oba, 1993). Available nitrogen and the heated water extraction nitrogen (HWEN) have corelation (Akatsuka & Sakayanagi, 1964). In Memuro continuous cropping experiment, the relationship of the HWEN of postharvest soil and soybean yield was investigated in 1994 (Fig. 6). With increase of the HEWN, soybean yield tended to increase. It is suggested that organic matter application increases biomass nitrogen, and contributes to yield increase.

D-D promotes mineralization from biomass nitrogen (Neve et al., 2004). D-D suppresses nitrification from ammonia nitrogen (Neve et al., 2004). Therefore, much ammonia nitrogen in soil will be kept by D-D. In the Memuro continuous cropping experiment, D-D was applied before one month of sowing. Therefore, it is thought that these effects influenced a soybean.

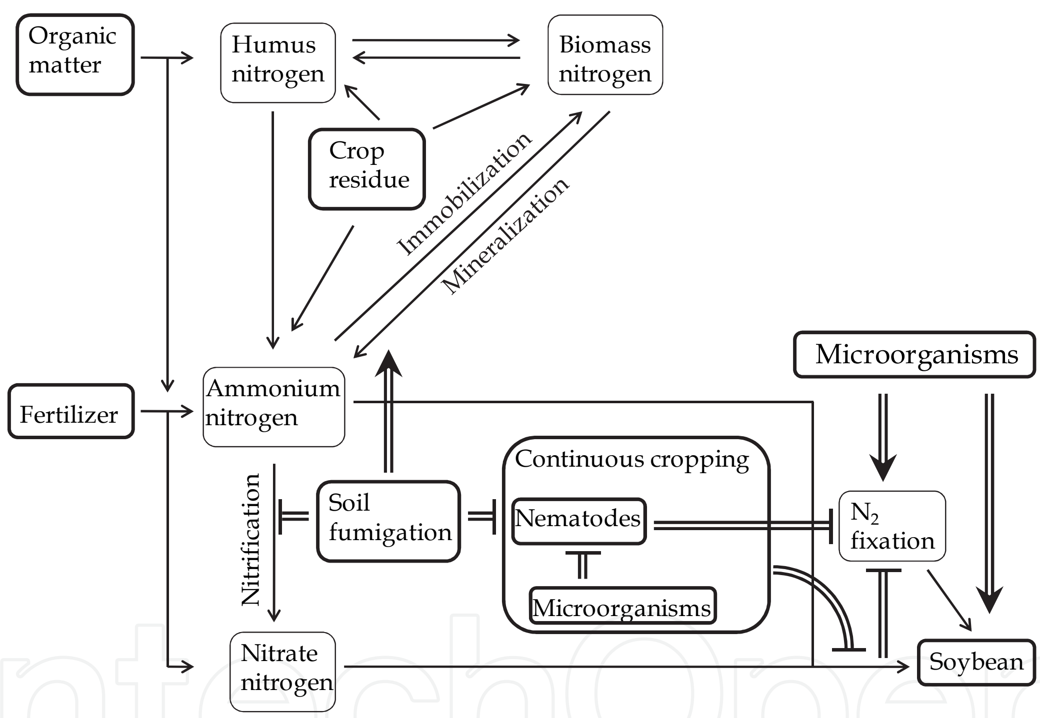


Fig. 7. The nitrogen flow and the factors influence to it.

4. Farming system and management to influence soybean yield

Farming system and management influencing soybean are described. Fig. 7 illustrates the results provided in Memuro continuous cropping experiment and the knowledge of the past.

4.1 Soil organic matter (SOM)

Soybean needs nitrogen absorption to get high yield. The Brazilian soybean absorbs approximately 100% of N need by N2 fixation, but in soybean of U.S.A. or Japan, fixed nitrogen is approximately 50% of N need (Graham & Vance, 2000). This may be connected with that soybean N2 fixation decrease at low temperature (F. Zhang et al., 1995). In other words, the nitrogen supply from soil probably become important so as to be a cold area.

4.1.1 Farming system

The soil organic matter (SOM) is broken down by the soybean planting (Cheng et al., 2003). This effect is called "priming effect". Soil carbon and nitrogen decrease in soybean continuous cropping in comparison with Gramineae - soybean rotation (Kelley et al., 2003; Wright & Hons, 2004). However, soybean-corn rotation can reduce the fertilizer nitrogen of 60kgN/ha/year in comparison with corn continuous cropping (Varvel & Wilhelm, 2003). The soil nitrogen mineralization quantity increases in soybean- corn rotation in comparison with soybean continuous cropping (Carpenter-Boggs et al., 2000). It is suggested that soybean breaks down SOM and will increase inorganic nitrogen, but soybean continuous cropping will cause a decrease of SOM.

In soybean rotation which incorporated alfalfa (*Medicago sativa*), the quantity of soil nitrogen mineralization increases greatly (Carpenter-Boggs et al., 2000). In soybean introducing to the permanent grass pasture, soybean yielded 3 t / ha at no chemical fertilizer (Diaz et al., 2009). One of the causes of these phenomena will be that pasture plant leaves much organic matter in soil.

4.1.2 Management

SOM increases by organic matter application. SOM is maintained by no-tillage (Wright & Hons, 2004). Because mineralization of soil nitrogen decreases by no-tillage, N2 fixation probably increases (van Kessel, 2000). These treatments are suggested to increase soybean yield.

4.2 Soybean cyst nematode (SCN)

4.2.1 Farming system

SCN inhibits the production of soybean. SCN does not increase by the cropping of non-host crop, but SCN increases by soybean cropping again (Asai & Ozaki, 1965). Gramineous crops such as corn and wheat are non-host crop of SCN. Soybean- corn rotation carried out in the northern part of U.S.A. (Varvel & Wilhelm, 2003; Xing & Westphal, 2009), but SDS by SCN and *Fusarium solani* occurs in this rotation (Rupe et al., 2003; Xing & Westphal, 2009). SDS can lead to defoliation of the leaflets, leaving the petioles attached to the plant after flowering (Rupe et al., 2003; Xing & Westphal, 2009). Pythium have a pathogenicity in soybean and corn and cause damping-off (B.Q. Zhang et al., 1998).

In the Southern U.S.A., soybean is cultivated by no-tillage in soybean - wheat double cropping (Bernard et al., 1996). No-tillage is used to corn, soybean, wheat and etc in U.S.A., and the cultivated area occupies 23% in U.S.A. (Triplett. Jr. & Dick, 2008). No-tillage reduces nematode density in soybean - wheat double cropping (Bernard et al., 1996). However, take-all (G*aeumannomyces graminis*) of wheat cannot be reduced in soybean- wheat double cropping (Cook, 2003).

Some plants are able to control nematodes. Probably Marigold controls nematodes with chemical substances such as α -terthienyl (Oka, 2010). The Brassicaceae plants control nematodes with isothiocyanates which is broken down from glucosinolates (Oka, 2010). The leguminous crops such as red clovers are probably available as trap crop reducing the egg density of SCN (Kushida et al., 2003).

4.2.2 Management

Nematodes may be controlled by organic matter application. The organic matter including inorganic nitrogen or chitinous substance is effective for nematodes control (Akhtar & Malik, 2000; Oka, 2010). The application of organic matter including antagonism microorganism will be effective (Oka, 2010). However, these effects will vary according to materials or adjustment methods.

4.3 Arbuscular Mycorrhizal (AM) fungi

With soybean, plant growth promoting rhizobacteria (PGPR) such as rhizobia and *Bacillus* form symbiosis (Bai et al., 2003; Cattelan et al., 1999; Gray & Smith 2005), and arbuscular mycorrhizal (AM) fungi form symbiosis, too (Troeh & Loynachan, 2003). The AM fungi increase N2 fixation (Antunes et al., 2006). The symbiosis with AM fungi helps phosphorus acid absorption of the crop (Harrison, 1998). The crops doing N2 fixation need a lot of phosphoric acid (Graham & Vance, 2000), and the symbiosis with AM fungi will be effective for soybean. Soybean and corn form symbiosis with AM fungi (Troeh & Loynachan, 2003), and AM fungi probably increases in soybean - corn rotation. Sugar beet was non-host crop of AM fungi, and soybean growth after non-host crop such as sugar beet was suppressed (Karasawa, 2004).

5. Conclusion

Soybean forms symbiosis with rhizobia. However, in low temperature area, the nitrogen absorption of soybean may not be served only in N2 fixation, and soil nitrogen probably becomes important. Soybean stimulates the decomposition of SOM, and can absorb nitrogen from soil. The crops such as gramineous crop or pasture plant supply organic matter to soil. No-tillage maintains SOM. Organic matter application increases SOM. Soybean yield probably increases by the combination of these treatments.

SCN inhibits the nitrogen absorption of soybean. By cropping of non-host crops or resistant varieties, SCN does not increase, but the cyst of SCN does not decrease. Soybean is affected by not only SCN but also pathogenic fungi such as *Fusarium*. On the other hand, soybean growth is promoted by PGPR (rhizobia, *Bacillus* and etc) and AM fungi. In soybean, it is necessary to decide farming system and management while considering these organisms.

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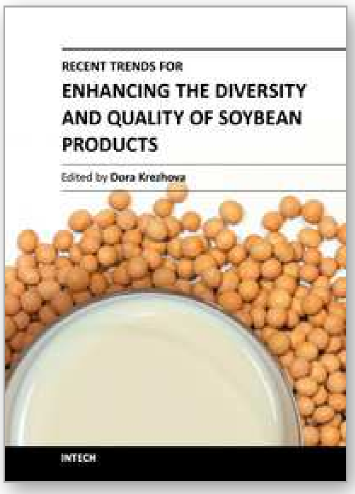

Recent Trends for Enhancing the Diversity and Quality of Soybean Products

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This book presents new aspects and technologies for the applicability of soybean and soybean products in industry (human food, livestock feed, oil and biodiesel production, textile, medicine) as well as for future uses of some soybean sub-products. The contributions are organized in two sections considering soybean in aspects of food, nutrition and health and modern processing technologies. Each of the sections covers a wide range of topics. The authors are from many countries all over the world and this clearly shows that the soybean research and applications are of global significance.