Japanese Journal of Plant Science ©2008 Global Science Books

Reducing Tillage and Fertilization in Humid, Temperate and Cool Temperate Regions

Kae Miyazawa*

National Agricultural Research Center for Tohoku Region, Cover Crop Research Team, 50 Harajuku-minami, Fukushima, Fukushima, 960-2156 Japan

Corresponding author: * **kae@affrc.go.jp**

ABSTRACT

Conservation tillage systems often promote germination and initial growth of crops on Andosol (fine volcanic ash soil), a predominant soil type in Japanese upland fields. Three main mechanisms are apparently responsible for better performance of seedlings under conservation tillage than under conventional tillage: stable soil water content facilitates crop germination and establishment; nitrogen accumulation at the soil surface promotes nitrogen uptake and growth of seedlings; and an undisturbed network of hyphae created by preceding cropping promotes the inoculum potential of arbuscular mycorrhizal fungi. Based on these findings, a new tillage method and cover cropping systems were developed which improve not only seedling performance but also crop yields. Improved fertilization efficiency attained using these systems can reduce external input in both tillage and fertilization.

Keywords: arbuscular mycorrhizal fungi, conservation tillage, cover crop, nitrogen dynamics, no-tillage

CONTENTS

INTRODUCTION

Intensive agriculture systems using machinery and fertilizers have raised crop yield to a level that can rarely be obtained under traditional labor-dependent, low-input systems. However, conversion to intensive production systems can reduce long-term soil productivity. A notable decrease in crop yields has already taken place in areas with severe soil degradation (Pimentel *et al*. 1986). Even in areas where such a yield reduction is not evident, it is merely compensated by the input of fertilizers; the fertility of the soil itself is actually declining (Gliessman 1998). To maintain the current production level, modern intensive agriculture requires continuous inputs of external energy and resources, which only exacerbates a vicious circle.

Furthermore, intensive agriculture practices engender global effects. Agriculture is one of the human activities that creates greenhouse gas emissions and pollutes surface water. Not only are fossil fuels consumed by agricultural machines: continuous tillage operation stimulates the release of carbon dioxide. Tillage operations by a moldboard plow can cause 13.8 times as much carbon release from soil as that under no-tillage (Reicosky 1997). Nitrous oxide is another important greenhouse gas that is released from crop fields. Nitrogen fertilization is a direct and indirect source of nitrous oxide emission (Smith *et al*. 1997; Ruser *et al*. 2001). Moreover, excessive application of phosphorus and its consequent runoff from farmland causes drastic changes in aquatic and marine ecosystems through eutrophication (Sharpley *et al*. 1994).

Conservation tillage systems and proper fertilization management are critical to improve agricultural sustainability and to reduce environmental impact. Conservation tillage system defined as “an ecological approach to seedbed preparation and soil surface management” (Lal 1989) encompasses many different tillage practices. Whereas conventional tillage system consists of complete range of primary and secondary tillage, conservation tillage generally consists of less intensive or completely no tillage operations. Adoption of conservation tillage systems, such as no-tillage, is easy in tropical, arid, and semi-arid regions because of the readily apparent benefits; yields are often greater under no-tillage systems than under a conventional tillage system (Robinson *et al*. 1984; Derpsch and Moriya 1999). Minimum disturbance of soil and plant residue cover can reduce major constraints for crop production in these regions: soil erosion by water and wind, destruction of soil structure, and drought hazard. However, such benefits are not always apparent in humid, temperate and cool temperate regions with excessive plant residues and wet soil conditions. Plant growth is often delayed under no-tillage because soil temperature is lowered in the presence of plant residues (Carter 1994). Reducing fertilization in combination with conservation tillage also seems difficult in such regions. Lack of mechanical incorporation and wet and poorly aerated soil conditions inhibit nutrient release from manure compost applied under reduced tillage (Miyazawa *et al*. 2004).

However, some evidence suggests the superiority of conservation tillage over conventional tillage in humid, temperate and cool temperate regions in the context of seed

Received: 29 February, 2008. Accepted: 19 March, 2008.

Invited Mini-Review

germination and seedling growth. Three main factors seem to be responsible for better performance of crops in early stages under conservation tillage: soil water content, nitrogen dynamics, and mycorrhizal activity. This review introduces studies that report on better seedling performance under conservation tillage systems in Japan. These studies were conducted on Andosol (fine volcanic ash soil), a common soil type in Japanese upland fields. Based on these findings, some new tillage and soil management systems have recently been developed, which improve not only seedling performance but also crop yield. Improved fertilization efficiency in such systems is expected to enable reductions in fertilizer input.

SOIL WATER CONTENT UNDER CONSERVATION TILLAGE

Soil water content is critical for seed germination and seedling establishment. Ogawa *et al.* (1988) investigated the effect of tillage methods on germination rates of soybean (*Glycine max* (L.) Merr., cv. 'Kitahomare') and on soil water content. The tillage treatments were conventional tillage (CT: moldboard plowing of 20-25 cm depth and rotary harrowing of 15-20 cm), no-tillage (NT: open seeding furrows of 5 cm depth), and reduced tillage (RT: rotary harrowing of 5 cm depth). The germination rates observed one month after sowing were 72, 93, and 91%, respectively, under CT, NT and RT treatments. Soil water contents at 2-4 cm depth, where soybean seeds were located, were 7.7, 15.8, and 18%, respectively. Similar results were obtained for a study of Hatanaka and Shiozaki (1987) using kidney bean (*Phaseolus vulgaris* L. cv. 'Himeteboh'), soybean (cv. 'Kitamusume'), and maize (*Zea mays* cv. 'Haney Bantam'). Adequate water contents under conservation tillage seem to have been a factor influencing the germination of these crops. Grater water content available under conservation tillage compared to that under conventional tillage was attributed to less water evaporation from the soil surface (Ogawa *et al.* 1988), and a higher value of solid phase distribution in soil under conservation tillage (Hatanaka and Shiozaki 1987).

Although greater water content is advantageous during the dry season, it becomes a constraint during the rainy season, especially in Japan. In recent years, upland fields are being converted from paddy fields for soybean and wheat production. Such fields generally have poor drainage. Under no-tillage, heavy rain creates puddles in wheel traces from previous cropping operations. The germination rate of soybean can be reduced to 20% if seeds are submerged at a few days after seeding because the germinating seeds need oxygen (Hamada 1993; Hamada *et al.* 2007). It is necessary to reduce the risk of submerging seeds and yet retain the advantages of conservation tillage of water retention during the dry season. A new reduced tillage system was developed to meet this requirement (Amaha *et al.* 2006; Yoshinaga 2006). This new tillage can be conducted using a commercially available rotary seeder (reverse-rotation gives better performance), from which some blades are removed. Approximately 20-cm-wide ridges (where seeds are sown) are left without tillage, while areas between ridges are tilled to a 10-13 cm depth. The soil that is churned up by blades forms a thin layer of soil cover on the top of non-tilled ridges (about 4-5 cm depth), and thereby creates an optimum seedbed condition. The presence of contrasting physical properties of tilled and non-tilled soil side-by-side can maintain the optimal water contents in ridges. Wetting and drying processes occur mainly in the tilled area because of its improved porosity; this acts as a buffer for water content fluctuation for ridges. Stable water content in no-tilled ridges improves not only the germination rate but also the growth and yield of soybeans. The biomass at the flowering stage and seed yield under reduced tillage were approximately 25% and 12.5% greater, respectively, than that under conventional tillage. This new reduced tillage system is also superior in terms of adaptability by farmers compared to no-tillage or other forms of reduced tillage for the following reasons: 1) it obviates the purchase of new machines for seeding, and 2) "ridging soil" at flowering, which is a common practice for soybean cultivation in Japan, is feasible for preventing weed infestation and lodging.

NITROGEN DYNAMICS UNDER CONSERVATION TILLAGE

Conservation tillage can improve crop growth in the early developmental stage via improved nitrogen utilization by crops. Superior nitrogen utilization of maize seedlings under reduced tillage has been reported (Hatanaka 1987). Maize (*Zea mays* L. cv. 'Honey Bantam') was grown under CT (moldboard plowing of 25 cm depth and harrowing to 15-18 cm), minimum tillage (MT: tilling only ridges to a 5 cm with a tiller), and RT (rotary plowing to a 10-15 cm depth). The nitrogen uptake by maize was approximately 30% higher under MT and RT than under CT until the pre-silking stage. Under MT and RT, the gas phase and macropores in soil were smaller than those under conventional tillage. Lower porosity of soil was inferred to have reduced nitrogen leaching and retained inorganic nitrogen in the maize rhizosphere. A similar result was reported by Miyazawa *et al.* (2004). Soybean (cv. 'Toyomusume') and wheat (*Triticum aestivum* L. cv. 'Haruyutaka') were grown under conventional tillage (moldboard plowing to 25 cm, rotary harrowing and spring-tooth harrowing to 5 cm) and reduced tillage (rotary harrowing to 5 cm only). Reduced tillage promoted early growth of both soybean and wheat, and the yield of wheat. The concentration of soil inorganic nitrogen was higher early in the season under reduced tillage than under conventional tillage. The basic intake rates measured immediately after tillage and fertilization operation were 12.60 and 0.67 mm h^{-1} under conventional and reduced tillage, respectively; the slower water infiltration rate might have promoted nitrogen retention and seedling growth.

Ogawa *et al.* (1988) reported that a higher concentration of soil inorganic nitrogen is not only caused by greater nitrogen retention under conservation tillage but also faster nitrogen mineralization. They conducted an incubation experiment with soil samples taken from plots that had been managed under CT, NT and RT for five years (the same tillage protocols in Ogawa *et al.* (1988) as described in the "Soil water content under conservation tillage" section). The amounts of nitrogen mineralized after 30 days of incubation at 30°C were 2.8, 5.0, and 6.4 N mg/100 mg dry soil, respectively, managed under CT, NT, and RT. Generally, root and stubble accumulate in surface soil in the absence of deep tillage. Development of dense root systems of maize and soybean near the soil surface under NT and RT was also reported (Sakai *et al.* 1988; Tsuji *et al.* 2002). These factors accelerate the accumulation of organic matter at the soil surface under conservation tillage. Therefore, soil under conservation tillage might have a greater nitrogen mineralization rate than that under conventional tillage if optimum temperature and moisture are provided.

The benefits of conservation tillage on crop growth, however, often decrease as crops mature; the yield difference between conventional and conservation tillage is often only very slight (Hatanaka 1987; Ogawa *et al.* 1988; Miyazawa *et al.* 2004). Ogawa *et al.* (1988) speculated that less nitrogen availability in later periods is a limiting factor for yield increase under conservation tillage. Integrating cover crops into conservation tillage might improve the nitrogen supply to crops in later stages, and thereby increase yields. Kobayashi *et al.* (2007) conducted a field study of soybean production (cvs. 'Suzuyutaka' and 'Fukuibuki') under three treatments: 1) NT with winter barley as a cover crop (NT-C: barley was mowed and shredded a day before soybean sowing to cover the soil surface), 2) NT without a cover crop (NT), and 3) CT without a cover crop (CT: rotary plow before soybean sowing). The yield of soybean under the NT-C treatment was approximately 50% higher than NT and CT treatment in 2001, and 30% higher in 2002. Kobayashi *et al.* inferred that nitrogen released from the barley residue, especially from immature grains, enhances the nitrogen supply to soybean during the pod-filling period. They also found greater soybean nodulation under the NT-C treatment than under the NT and CT treatments. Improved nitrogen supply under conservation tillage and cover crop that synchronize nitrogen release with crop demand will facilitate reduction of nitrogen fertilization. The cover crop effect on the colonization rate of arbuscular mycorrhizal fungi, which is discussed in the next section, was not detected in this system at 30 days after sowing (Miyazawa, unpublished data).

ARBUSCULAR MYCORRHIZAL COLONIZATION UNDER CONSERVATION TILLAGE

Andosol, with rich Fe and Al oxide, has a high phosphate-fixing capacity; phosphate availability is often a limiting factor for crop growth (Tsuji *et al*. 2006). One plant strategy to acquire phosphorus is a symbiosis with arbuscular mycorrhizal (AM) fungi (Harrison 1997). AM fungi colonize the cells of the root to obtain carbon from host plants; in return, the host plants receive phosphate and other mineral nutrients through the external hyphae network of fungi. The effect of conservation tillage on AM fungi colonization is reported differently among studies of the relevant literature: faster colonization of AM fungi under no tillage systems than under conventional tillage system is reported; other studies have found no differences among different tillage systems (Usuki *et al*. 2005).

Different results might arise from differences in the crop species. Many studies have shown rapid AM colonization on maize roots and enhanced maize phosphate uptake under conservation tillage (e.g. O'Halloran *et al*. 1986; Usuki *et al*. 2005, 2007). Fewer studies have assessed soybean: little, if any, effect of tillage on AM colonization on soybean root and soybean phosphate uptake has been detected (McGonigle *et al*. 1999; Miyazawa *et al*. 2004). Colonization of AM fungi on winter crops is also reportedly less affected by tillage operations. Usuki *et al*. (2005) found no difference in colonization rates of AM fungi, phosphorus uptake, and biomass of oat (*Avena sativa* L. cv. 'New Almighty') under conventional and no tillage treatments, at the same field where they detected significant differences in these parameters of maize (cv. 'Pioneer 33G26'). A 10-year-long field experiment using various summer crops and winter crops also revealed that winter crops are more dependent on phosphorus fertilizer than summer crops (Tsuji *et al*. 2006). Low temperatures during winter cropping might minimize the effects of tillage on the speed of AM fungi colonization because of the temperature requirement for spore germination and hyphae development of AM fungi (Raju *et al*. 1990).

However, some reports have described a lack of significant differences in AM colonization rates under different tillage systems, even for maize (Gavito and Miller 1998; Nakamoto *et al*. 2001). Therefore, another possible factor that explains different results was investigated using maize: the type and harvest timing of precedent crops (Usuki *et al*. 2007). The AM colonization on maize roots and maize growth were investigated under four different preceding-winter-crop treatments (**Fig. 1**): 1) oat, 2) oat early harvest, 3) komatsuna (*Brassica chinensis* L. var. Komatsuna), and 4) komatsuna followed by oat. Komatsuna is a non-mycorrhizal plant. Maize (cv. 'Pioneer 33G26') was sown either under CT (rotary plowing to 15 cm in depth) or NT (opening seeding furrows of 5 cm depth without tillage). The initial colonization rate of AM fungi on maize roots (20 days after sowing) was in the following order: oat > komatsuna-oat > oat early harvest > komatsuna. In the NT treatment, rates of AM fungi colonization were increased by approximately 28% under oat, but 18% under oat early harvest, and 12% under komatsuna-oat and komatsuna. The biomass increase of maize by NT at 38 days after sowing was also the largest under oat. The maintenance of a well-developed hyphal network by the existence of host plant until maize sowing seems to promote the no-tillage advantage in AM fungi colonization.

If an undisturbed hyphal network left from the preceding winter crop was important to maximize NT advantage in AM fungi colonization, maintaining living hyphae network during crop growth might be even more effective. Introducing a mycorrhizal cover crop as a living mulch can provide such a condition for crops. Use of white clover (*Trifolium repens* L. cv. 'Huia') as a living mulch significantly increased the rate of AM fungi colonization, phosphate uptake, and yield of maize (*Zea mays* L. cv. 'DeaHT') (Deguchi *et al*. 2007). Their field experiment consisted of seven treatments, which are categorizable into three groups: 1) NT with living mulch (LM1, LM2), 2) NT, and 3) CT (P0, P1, P2, P3). Living mulch was established in the prior year of maize planting by sowing white clover in August. Other plots were maintained fallow. The LM treatment was further divided into two treatments: living mulch shoots clipped before maize sowing and residues left in the plot (LM1), and residues removed (LM2). The CT treatment was also divided into four different phosphate fertilization treatments: no phosphate fertilization (P0), phosphate fertilized at the rate of 500 kg P_2O_5 ha^{-1} (P1), 1000 kg P_2O_5 ha^{-1} (P2), and 2000 kg P_2O_5 ha^{-1} (P3). Sufficient amounts of nitrogen and potassium were applied in all treatments. An astonishing difference was observed in AM fungi colonization rate in the early developmental stage; the colonization rate reached approximately 60% under LM1 and LM2, but it was less than 5% under the remaining five treatments. Furthermore, although LM received no phosphate fertilization, the phosphorus uptake and yield of maize under living mulch treatments were equivalent to or even greater than under P3. The living hyphal network provided to maize during the initial root growth seems to be an important benefit. Consequently, when combined with the use of appropriate living mulch species, no-tillage might reduce phosphate fertilization in maize production on Andosol.

SUMMARY AND CONCLUSION

Plant responses to tillage operations are not dependent on tillage protocols *per se*. The same tillage protocol creates different soil environments depending on climate conditions and soil types (Boone 1988; Carter 1994). Observing plant responses to tillage under specific climate and soil conditions, and determining factors that influence the plant responses facilitate the development of suitable conservation

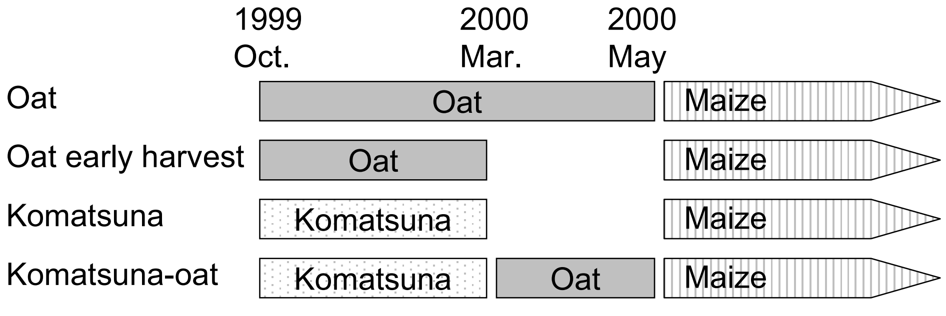

Fig. 1 Outline of winter crop treatment in Usuki *et al*. (2007). Winter crops (oat or komatsuna) were sown on 14 October and harvested either at the end of May ("Oat" treatment) or March ("Oat early harvest", "Komatsuna", and "Komasuna-oat" treatment). Oat was sown after Komat-suna harvest in "Komatssna-oat" treat-ment, and harvested at the end of May. Maize was sown on 2 June in all treatments.

tillage systems. A new tillage method and combination of conservation tillage and cover cropping are promising systems developed on Andosol soils in Japan; they might reduce external input in both tillage and fertilization. In addition to reduction of all energy input and environmental impact, recovery of agro-ecosystem functions by these systems is anticipated, as will be reported in the near future.

REFERENCES

Amaha K, Yoshinaga S, Koizumi S (2006) The situations and problems in wheat-soybean and buchwheat-OSR (oil seed rape) relay-intercropping system and soybean cultivation with inverse strip tillage seeding. *Research Journal of Food and Agriculture* **29**, 15-19 (in Japanese with English abstract)

Boone FR (1988) Weather and other environmental factors influencing crop responses to tillage and traffic. *Soil and Tillage Research* **11**, 283-324

Carter MR (1994) A review of conservation tillage strategies for humid temperate regions. *Soil and Tillage Research* **31**, 289-301

Deguchi S, Shimazaki Y, Uozumi S, Tawaraya K, Kawamoto H, Tanaka O (2007) White clover living mulch increases the yield of silage corn via arbuscular mycorrhizal fungus colonization. *Plant and Soil* **291**, 291-299

Derpsch R, Moriya K (1999) Implications of soil preparation as compared to no-tillage, on the sustainability of agricultural production: experiences from South America. In: Reddy MV (Ed) *Management of Tropical Agroecosystems and the Beneficial Soil Biota*, Oxford & IBH, New Delhi, pp 49-65

Gavito ME, Miller MH (1998) Early phosphorus nutrition, mycorrhizae development, dry matter partitioning and yield of maize. *Plant and Soil* **199**, 177-186

Gliessman SR (1998) *Agroecology: Ecological Processes in Sustainable Agriculture*, Ann Arbor Press, Chelsea, 357 pp

Hamada Y (1993) Developing no-tillage seeding system for soybean – a case study in Aichi prefecture. *Japanese Journal of Crop Science* **62**, 470-474 (in Japanese)

Hamada Y, Shaku I, Sawada Y, Kojima H (2007) Factors causing submergence damage on soybean seedling emergence under no till culture conditions. *Japanese Journal of Crop Science* **76**, 212-218 (in Japanese with English abstract)

Harrison MJ (1997) The arbuscular mycorrhizal symbiosis: an underground association. *Trends in Plant Science* **2**, 54-60

Hatanaka T, Shiozaki H (1987) Effect of minimum tillage on upland soil conditions and yields of grain crops. *Journal of the Japanese Society of Soil Physics* **54**, 2-12 (in Japanese with English abstract)

Hatanaka T (1987) Effect of minimum tillage farming for upland crops in cold region. *Nogyo-gijutu* **42**, 251-256 (in Japanese)

Kobayashi H, Uchida T, Shimazaki Y (2007) Increased soybean yield by cover crop of winter barley. *Agriculture and Horticulture* **82**, 1267-1272 (in Japanese)

Lal R (1989) Conservation tillage for sustainable agriculture: tropics versus temperate environments. *Advances in Agronomy* **42**, 85-197

McGonigle TP, Miller MH, Young D (1999) Mycorrhizae, crop growth, and crop phosphorus nutrition in maize-soybean rotations given various tillage treatments. *Plant and Soil* **210**, 33-42

Miyazawa K, Tsuji H, Yamagata M, Nakano H, Nakamoto T (2004) Response of soybean, sugar beet and spring wheat to the combination of reduced tillage and fertilization practices. *Plant Production Science* **7**, 77-87

Nakamoto T, Yamagishi J, Oyaizu H, Funahashi T, Frossard E, Mozafar A (2001) The spatial variability patterns of maize growth and root colonization by arbuscular mycorrhizal fungi in a small field. *Plant Production Science* **4**, 249-254

Ogawa K, Takeuchi Y, Katayama M (1988) Influence of minimum tillage on soil properties and crop yields in gleyic Andosol. *Research bulletin of the Hokkaido National Agricultural Experiment Station* **150**, 57-90 (in Japanese with English abstract)

O'Halloran IP, Miller MH, Arnold G (1986) Absorption of P by corn (*Zea mays* L.) as influenced by soil disturbance. *Canadian Journal of Soil Science* **66**, 287-302

Pimentel D, Dazhong W, Eigenbrade S, Land H, Emerson D (1986) Deforestation: interdependency of fuelwood and agriculture. *Oikos* **46**, 404-412

Raju PS, Clark RB, Ellis JR, Maranville JW (1990) Effect of species of VA-mycorrhizal fungi on growth and mineral uptake of sorghum at different temperatures. *Plant and Soil* **121**, 165-170

Reicosky DC (1997) Tillage-induced CO_2 emission from soil. *Nutrient Cycling in Agroecosystems* **49**, 273-285

Robinson EL, Langdale G.W, Stuedemann JA (1984) Effect of three weed control regimes on no-till and tilled soybean (*Glycine max*). *Weed Science* **32**, 17-19

Ruser R, Flessa H, Schilling R, Beese F, Munch JC (2001) Effect of crop-specific field management and N fertilization on N_2O emissions from a fine-loamy soil. *Nutrient Cycling in Agroecosystems* **59**, 177-191

Sakai N, Sunohara W. Yonekawa S. Tsunoda K (1988) Assessment of no-tillage farming IV. Soil changes and root growth. *Japanese Journal of Farm Work Research* **23**, 25-32 (in Japanese with English abstract)

Sharpley AN, Chapra SC, Wedepohl R, Sims JT, Daniel TC, Reddy KR (1994) Managing agricultural phosphorus for protection of surface waters – issues and options. *Journal of Environmental Quality* **23**, 437-451

Smith KA, McTaggart IP, Tsuruta H (1997) Emissions of N_2O and NO associated with nitrogen fertilization in intensive agriculture, and the potential for mitigation. *Soil Use and Management* **13**, 296-304

Tsuji H, Yamamoto H, Matsuo K, Usuki K (2002) Effect of no-tillage on the root system development of groundnut, maize and soybean in Andosol. *Root Research* **11**, 43-49 (in Japanese)

Tsuji H, Yamamoto H, Matsuo K, Usuki K (2006) The effect of long-term conservation tillage, crop residues and P fertilizer on soil condition and responses of summer and winter crops on Andosol in Japan. *Soil and Tillage Research* **89**, 167-176

Usuki K, Yamamoto H, Tazawa J, Matsuo K, Tsuji H (2005) Effect of reduced tillage relation to arbuscular mycorrhiza development on the growth of maize and oat in an Andosol field in central Japan. *Japanese Journal of Crop Science* **74**, 417-421 (in Japanese with English abstract)

Usuki K, Yamamoto H, Tazawa J (2007) Effects of previous cropping and tillage system on growth of maize and symbiotic association with arbuscular mycorrhizal fungi in central region of Japan. *Japanese Journal of Crop Science* **76**, 394-400 (in Japanese with English abstract)

Yoshinaga S (2006) Soybean cultivation with inverse strip tillage. *Agriculture and Horticulture* **81**, 606-611 (in Japanese)

JAPANESE ABSTRACT

日本の耕地の多くを占める黒ボク土において、作物の発芽や初期生育が慣行耕起にくらべて保全型耕起（不耕起や簡易耕起など）で促進される事例が報告されている。その主要な3つのメカニズムとして、保全型耕起では、土壌の水分含有量が安定しており種子の発芽や定着を促進すること、地表面に窒素が蓄積し実生の窒素吸収を促進すること、そして前作の菌根菌の菌糸ネットワークにより作物の根への菌根菌感染が促進されることが挙げられる。近年これらの知見を元に、初期生育だけでなく収量の増加も可能にする新たな保全型耕起法や、カバークロップ技術が開発されてきた。これらの新たな耕起や栽培技術は、耕起に必要な労力と施肥両方の削減を実現する可能性がある。