7. GROWING TECHNIQUES OF SOYBEAN IN JAPAN

Shigeo MATSUMOTO* and Torao OHBA*

Ecotypes of Soybean Varieties and the Local Distribution

Soybean varieties are remarkably different in growing period. From seeding to maturing one needs 190 days as the longest and 90 days as the shortest.

Further, in the growing period there are two terms: one from seeding to flowering and the other from flowering to maturing, which are also composed of days different in the varieties. Upon this fact of the different days needed for flowering and maturing, Fukui and Arai classified in 1951 soybean varieties in nine ecotypes as shown in Table 1.

Table 1. Ecological Types of Soybean Varieties

Ecological types	I		II			III		IV	V
	a	b	a	b	c	b	c	c	c
Period from germination to flowering	very short	very short	short	short	short	medium	medium	long	very long
Period from flowering to ripening	short	medium	short	medium	long	medium	long	long	long

(Fukui and Araki, 1951)

On the other hand, when daily average temperature is not less than 12°C, the germination and ripening of soybean are scarcely disturbed by late or early frost. So, Ohba considered that the season of which daily average temperature is not less than 12°C is the period possible to do soybean cultivation. Fig. 1 shows the number of days of not less than 12°C in temperature at different regions in Japan. This figure makes us know that Japanese western part consisting of five regions: Tokai, Kinki, Chugoku, Shikoku and Kyushu, has, generally to say, more than 200 days of not less than 12°C in daily average temperature. The only exception is the mountaineous area of inner land where the 200 days are not completed. In most of the regions where are possible to cultivate soybean, being favoured by more than 200 days of a nice average temperature, any ecotype of the varieties can be applied from I a type of extremely early maturing to V c type of extremely late maturing. But the actual observation of the regions makes report that some varieties different in maturation time are selectively applied in more south-western area, so as to take advantage of the altitude of land and to escape from damages given by insects and climatic hardness. Here is used only a part of the period possible for soybean cultivation and introduced some methods different in cropping seasons. As a result, there are, as shown in Fig. 2, regionally distributed different ecotypes of soybean varieties.

Specially, in Kyushu region, are cultivated two types of varieties remarkably different in cropping seasons; one type seeded from late March to middle May and yielded from late July to middle August; the other type seeded from late June to early July

* Second Agronomy Division, Tohoku National Agricultural Experiment Station, Morioka-shi, Japan.

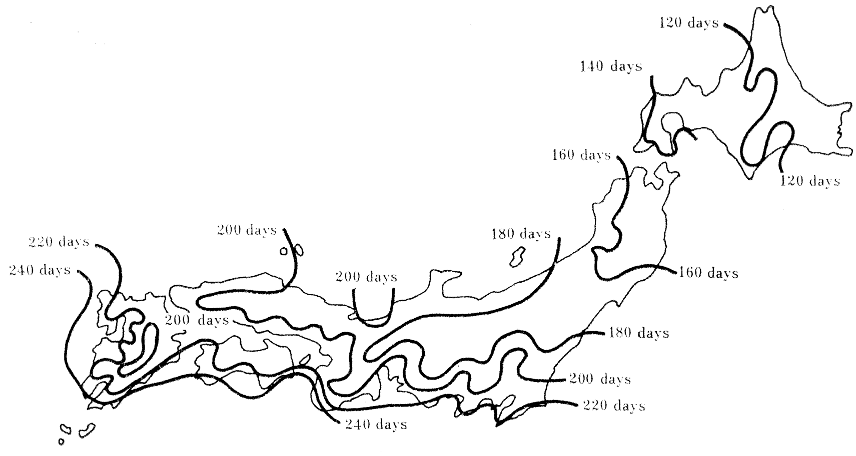


Fig. 1.

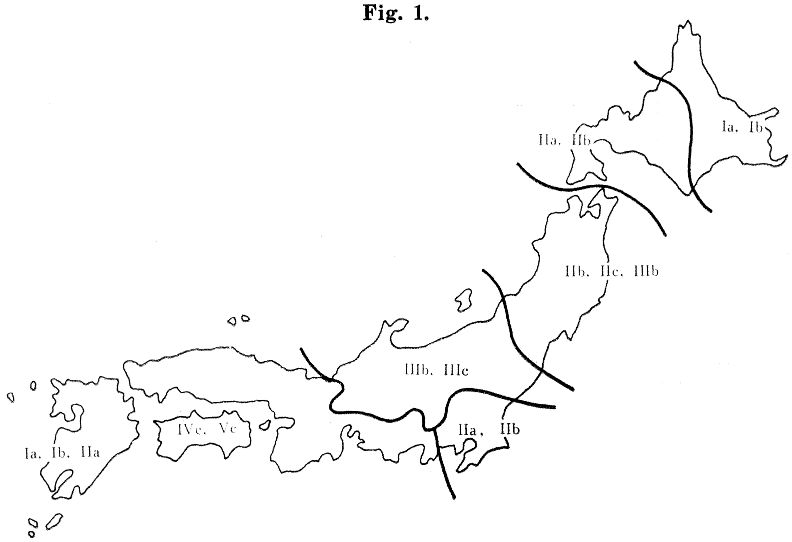


Fig. 2.

and yielded from late October to late November. On a viewpoint of yielding season, the former type is composed of early maturing varieties that are called summer soybean and the latter type of late maturing ones called autumn soybean. The distribution of summer and autumn soybeans in Kyushu region is as shown in Fig. 3. The main cause dividing the region into two zones is just the different abundance of insect pests.

Soybean Cultivation Method in the West Japan

1. Summer soybean cultivation

The early maturing varieties called summer soybean belong to Ia, Ib and IIa of ecotype. These varieties of comparatively high thermo-sensibility and low photo-sensibility would get in flowering period with a small amount of vegetation growth. It is needed, therefore, to begin the seeding as early as possible to ensure a sufficient vegetation growth and to increase the yield.

Many of summer soybean varieties are of small seed, high content of protein and

Fig. 3.

shorter period for maturation. As they do not occupy the field for a long period, the inter-cropping or rotation is easy to be established, combinating them with the preceding and succeeding crops.

In Kyushu region, the flowering period of summer soybean precedes a little to rainy season in the course of cultivation. So, in the case that the amount of vegetation growth comes to be too much before flowering, the soybean grows so spindly as to be suffered from lodging, because of insufficient sunshine in the rainy season. In other case, it is feared that a rainy season with little precipitation would sometimes give a damage from drought. But this type of cropping is still important as it is effective for escaping from the damages caused by insects like lima-bean pod borer (*Etiella zinckenella* Treitschke) and bugs as well as from those caused by typhoon after middle August.

Early maturing varieties in the north Japan are the same as so called summer soybean in the west Japan, so far as both have a short period of growth. But the former would make a small amount of growth in the fields of the west Japan where it is high in temperature and short in day length. The high yield can not be expected there. Further, a high temperature during maturation would cause a lot of shattering and rotten seeds. As a conclusion, it is not good to cultivate early maturing varieties of the north in the west regions of Japan.

2. Autumn soybean cultivation

The late maturing varieties called autumn soybean belong to IVc and Vc of eco-type. These varieties hold low thermo-sensibility and the higher photo-sensibility as they are the later maturing ones. The autumn soybean makes well thickened seeds, as the ripening period is favoured by the temperature conditions like in the northest region. With a long period needed for their growth, autumn soybean varieties are expected to achieve a high yield. But the problem is frequent assaults of typhoon that comes during the period from a little before flowering time until maturing. The typhoon causes such damages as blossom failure in fertilization and leaf falling or lodging which decrease assimilation capacity, so that unexpected yield may be got many times. It is, therefore, well understandable that in Kyushu region autumn soybean is applied in the northern district and mountaineous area to which typhoon does harm rather a little.

Though plain field makes possible to use a long period for soybean cultivation, autumn soybean is not applied there for because of insect injury, that is, soybean pod gall midge (*Asphondylia* sp.) and soybean stem miner (*Melanagromyza sojae* Zehntner). However, some reports let us know that the cultivation zones of summer soybean and autumn one are alternated somewhere, according to the change of insects occurrence in a long course of years.

3. Inoculation of root nodule bacteria

The inoculation of root nodule bacteria was expanded when the soybean cultivation was active, but at present it is little applied. Either in present dry fields in alternative land use system, or in a case of gravel culture, the root nodule bacteria are found on the roots, avoiding the necessity of inoculation. This bacteria shows its excellent multiplication in the soil which holds neutral or weak acidity. And being aerobic, it multiplies in soft soils where air and water permeate easily. In the virgin field for soybean cultivation and its neighboring area, where any natural taking of root nodule bacteria can not be observed, it would be effective to inoculate capable root nodule bacteria one time on the determination of soil acidity and ground water stagnation.

4. Fertilizer application

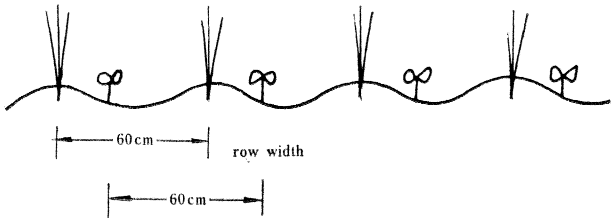
The farmers who are cultivating soybean regard using new varieties as the most reliable way for higher yield from their experiences, and pay due attention to the improvement of nutrient supplying factors such as rational fertilization, organic matter application, soil fertility increment, as well. But concerning the application of compost, its applying amount depends on the importance of soybean in the rotation system. In many cases, compost is not used directly in soybean cultivation.

Each farmer applies very different amount of fertilizer. Recently there are increased farmers who use compound fertilizers for soybean, as it is easier. The fertilization amount is supposed to be about 200 kg/ha as a standard. The amount of fertilizer application depends upon the soil fertility of each locality, and general pattern is 0–20 kg of N, 40–100 kg of P_2O_5, 400–100 kg of K_2O, each par hectar.

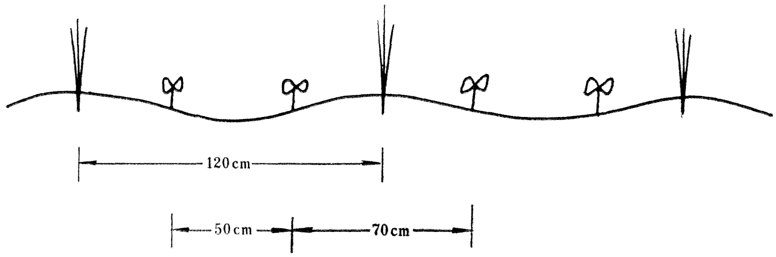
5. Rotation system

A long or middle term rotation system including soybean is rarely programmed in the west Japan. In most cases in the west Japan, soybean is cultivated in a short term rotation system, alternating the crops of wheat and soybean every year.

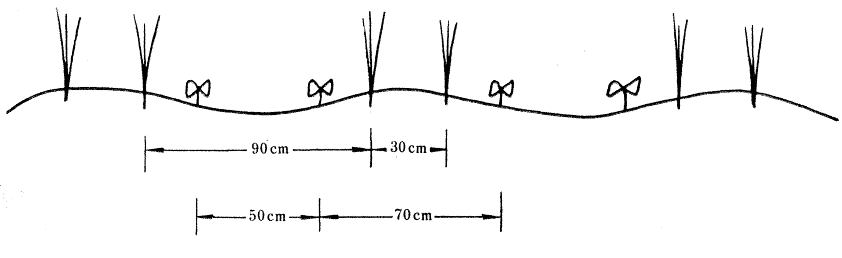
The cropping system including summer soybean is composed of three crops per year in Kyushu area: first crop; naked barley, wheat or two-rowed barley; second; summer soybean; third; foxtail millet, upland rice, autumn vegetables, buckwheat, broom corn, autumn potato or italian ryegrass. Summer soybean is cultivated between the rows



a) a row soybean between the narrow ridges of winter cereals



b) two rows soybean between the broad ridges of winter cereals



c) two rows soybean between the grouped rows of winter cereals

Fig. 4.

of barely plants; soybean seeds are sown about 20 to 40 days before the harvest of barley. Various planting patterns are shown in Fig. 4.

Autumn soybean cropping is observed in Kyushu area being combined in the two cropping system per year rotated with barley, rape, vegetables or tobacco.

6. Problems in future

1) Breakthrough of yielding: The average yielding of soybean in the west Japan. covers 1.1 to 1.2 ton/ha, which is lower by about 20% than in the producing area for marketable soybean in the east Japan. Recently high yielding examples exceeding in

some cases 5 ton/ha are got in the dry field converted from paddy field. So, it is needed to study how to improve the physico-chemical properties of ordinary fields up to nearly the same level as those of the converted fields.

2) Establishment of mechanized cultivation system using small type machine: As soybean is cultivated most between barley rows in a small scale, it is necessary to put in a mechanized cultivation system such works now done by manual labor as seeding, weeding of intrarow spacing, reaping, drying, threshing and cleaning.

Soybean Cultivation Method in the East Japan

1. Characteristics of soybean cultivation in the east Japan

1) Climatic conditions: As shown in Fig. 5, soybean cultivation in the east Japan is carried out in the period of daily average temperature not less than 12°C, like in the west Japan. But the east Japan, which is extended in the direction of north to south geographically, contains the areas of different possible cultivation periods: about 145 days in Hokkaido area and 190 days in the southern Tohoku and Nagano areas.

The climatic conditions for each period of soybean cultivation in Morioka, for example, are as follows; 14 hours of day length, 14°C of average temperature and about 100 mm of monthly rainfall for the seeding period (from middle May to late May); 13 hours of day length, 24°C of average temperature and about 160 mm of monthly rainfall for the flowering period (from late July to early August); 11 to 12 hours of day length and 12°C to 15°C of average temperature for the maturing period (from late September to middle October).

2) Cropping system: The cropping systems for soybeans vary, according to the climatic conditions, in the areas. Specially, it is apt to be multified in recent years. But system, the single cropping in a year consisting of beans to beans (or root vegetables or wheat) is the representative cropping system of Hokkaido. And these beans are soybeans, azuki beans and kidney beans which are alternately cultivated in a single cropping system. Three croppings each two years consisting of tobacco (or millet or potato), wheat and then soybeans, represent the corpping system of the northern Tohoku. The soybean is seeded between wheat rows and intercropped for 40 to 60 days until the harvest of wheat. In the areas of southern Tohoku, Niigata and Nagano, the representing system is two croppings in a year of barley (or wheat) to soybean. Similarly to the preceding case, soybeans are mostly intercropped between barley or wheat rows for 20 to 40 days, a comparatively short period. Recently, there are increased various methods such as late soybean seeding after the harvest of barley or wheat and as the soybean cultivation after upland rice or vegetables.

2. Cultivation methods

1) Varieties: As mentioned above, the varieties are different in each locality. In Hokkaido, they are of Ia and Ib types (Karikachi, Koganejiro, Kitamijiro etc.), in northern Tohoku, Ia and IIb types (Tokachi-nagaha, Raiden, Yamashirotama, etc.), in southern Tohoku and Shin-Etsu, IIb–IIIc types (Raiden, Miyagishirame, Okumejiro, Shiromeyutaka, Fujiminori, etc.) and in Kanto, of IIa and IIb types (Norin No. 2, Tachisuzunari, Shinmejiro, etc.).

2) Seeding time: When the daily average temperature rises up to be about 12°C in spring, the seeding shall be started, and the earlier the seeding the more the growth. In the expectation to get surely the highest yield, the optimum time of seeding lies from middle to late May approximatively, in the east Japan, even though it is not unanimous, depending on locality, variety and/or cultivating condition. At Morioka, Tokachi-nagah (Ia type) or Raiden (IIb type) seeded at the optimum time, would attain to the flowering period at the accumulated temperature of 1180°C or of 1350°C (i.e. accumulation

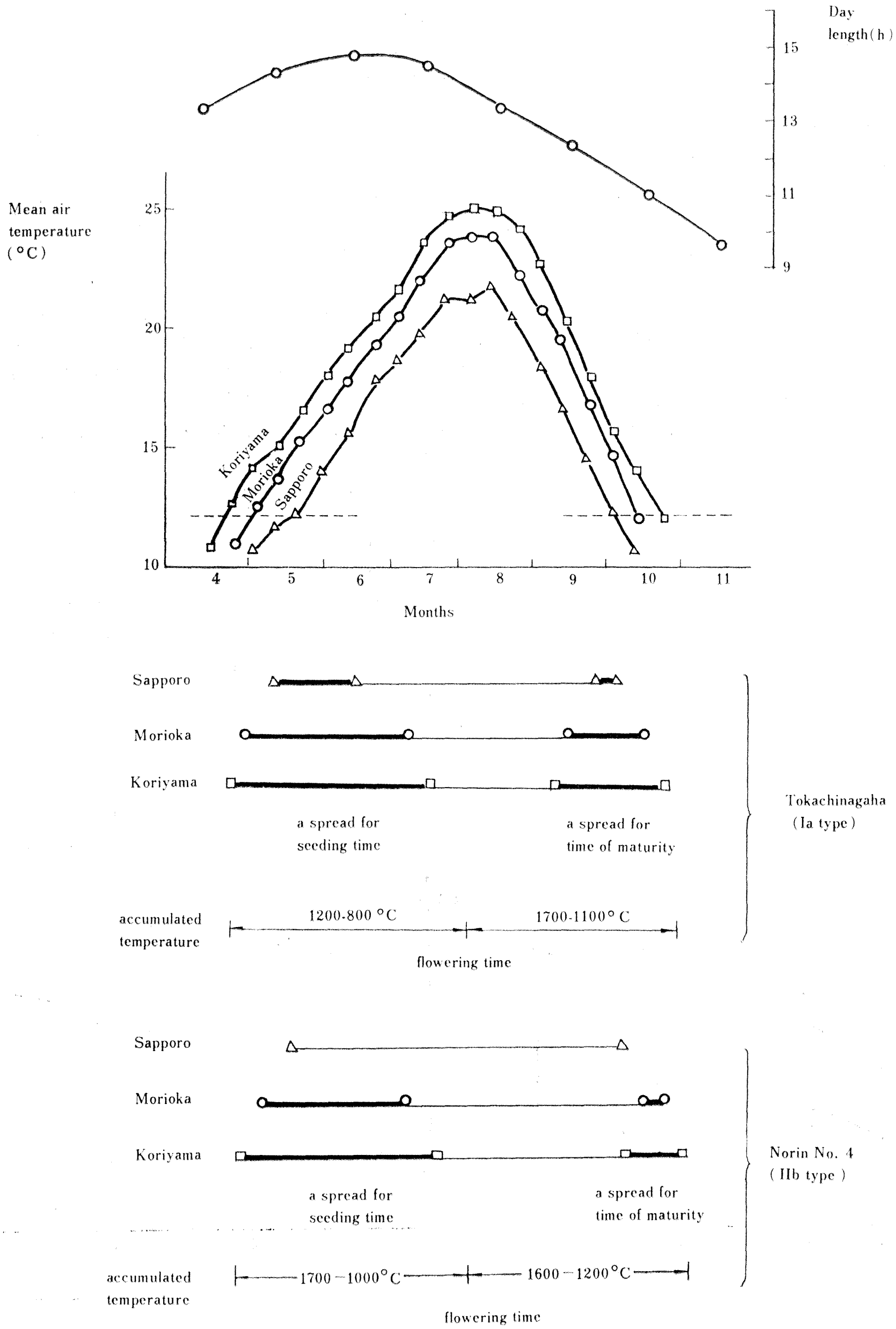


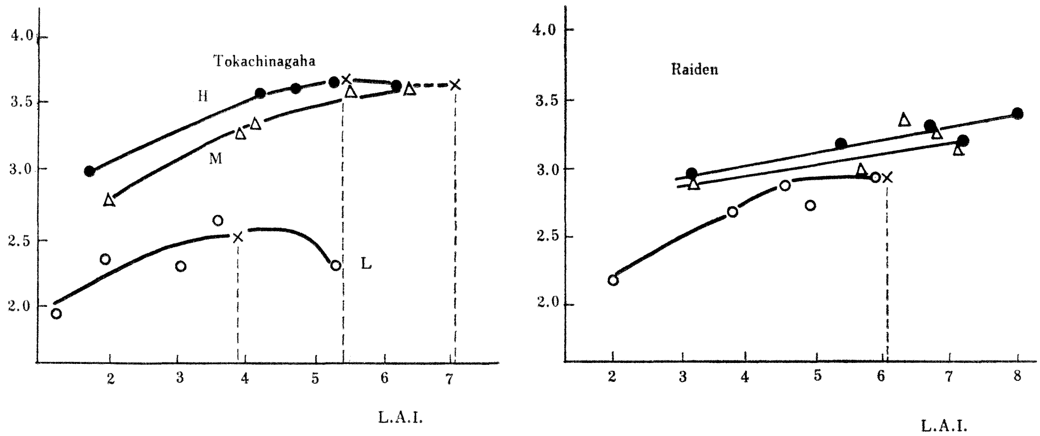
Fig. 5.

of daily average temperatures), and then afterwards to the maturing period at that of 1450°C.

If the seeding time is delayed beyond the optimum chance, the growth period is shortened, and the growth and yield are also decreased. Seeding after late July or early August would not result in ripening, because of low temperatures in the latter half of growing period. But if the variety and planting rate are appropriately designed, the decrease of yield would not be seriously influenced by the late seeding, so far as the lateness is limited. When the yield handicap, possibly due to late seeding, is somewhat compensated by introducing such advanced technics as mentioned above and 2 ton/ha is assumed as an expected yield. The minimum accumulated temperatures needed at Morioka for seeding to flowering and flowering to maturing is, for the variety of Tokachinagaha, 800°C and 1100°C, respectively. The limiting time for late seeding, estimated from these data, must be till middle June at Sapporo and middle July in Fukushima and Ibaragi areas. The period possible to seed is 20–30 days for the former and 60–70 days for the latter. This information is effective to disperse the concentration of labor in spring farm works. Specially in the south area of Morioka, the seeding time can be selected in a wide range. In fact, the soybean cultivation system with late and dense seeding from middle June to early July after the harvest of barley or wheat has begun to spread in those areas, because tractors are being introduced into the soybean cultivation as well as the preceding crop.

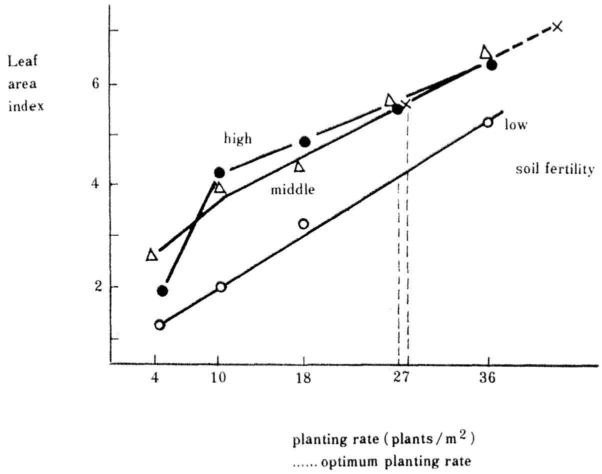
3) Planting rate: The propriety of planting are influences on the growth and yield of soybeans, samely as do the seeding time and the fertilizer amounts. There have mostly been applied the varieties of long stem, easy to lodge and needing less fertilization so that they were generally planted sparsely, however most of new varieties which are now under breeding are improved to avoid spindly growth and vine growth as well as from lodging, and to be adaptable to fertile soil. With the appearance of these new varieties, it is often reported that they are suitable to the dense planting. Examples of some experiments will be presented as follows.

In Figs. 6 and 7 is shown the comparison of the optimum amount of growth, indicated by the leaf area index at the maximum, in various growing conditions. These Figures suggest the general trend that the optimum leaf area index is lower in the case of early varieties than in the case of middle and late ones, as well as being lower in the field which has low fertility than in that of high fertility. Taking the result of



Soil fertility H : high
M : middle
L : low
x...................... Optimum leaf area index
L.A.I. Leaf area index at maximum luxuriant growth time

Fig. 6.



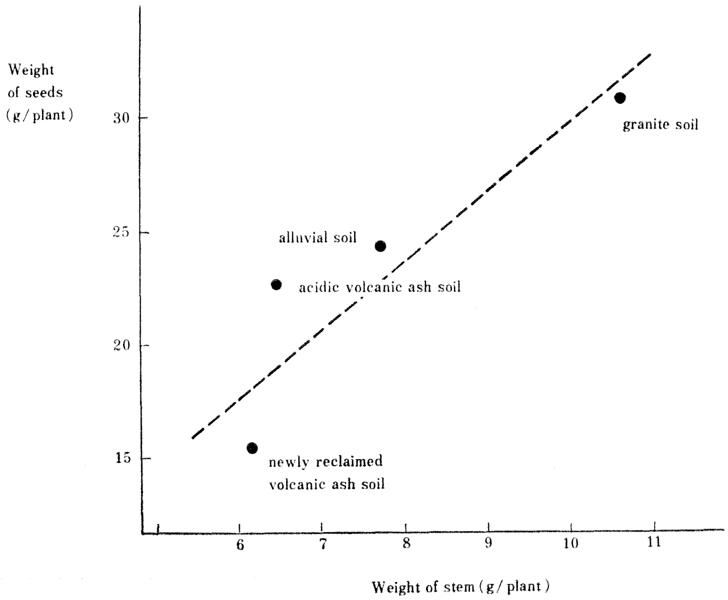


Fig. 7.

other experiments into consideration, the optimum leaf area index at the maximum luxuriant growth time in the Tohoku area can be estimated to the about 4 to 5.5 for Tokachinagaha and about 5 to 6.5 for Raiden. The planting rate to ensure this growth amount in the case sown at the standard seeding period (from middle May to early June) is 20 to 30 plants per square meter for Tokachinagaha (early variety: Fig. 7) and about 12 plants per square meter for Raiden (middle variety). In the south areas of Morioka, the lesser plant growth should be recompensed by a dense planting, in the case of late seeding (from middle June to early July). The density should be 20 to 30 plants per square meter, when applied Raiden.

4) Fertilizer application: Soybean takes up diffierent amounts of nutrient, de-

pending on the cultivation condition. For example, in the case when variety Norin No. 4 was grown on the volcanic ash soil of Morioka and yielded 3 ton/ha, the average nutrient uptake was, N: 23.1 kg, P_2O_5: 5.6 kg, K_2O: 17.8 kg (Kurihara et al.). In my experiment, the contents of N, P, and K in the leaf at the end of flowering are desirable to be 5.5, 0.35–0.42 and 2.3 (in percent/dry matter) respectively, so far as it is designed to ensure almost the same yield as mentioned above. But, the fertilizer amount to ensure such yield or plant-nutritional condition as aforesaid, depends on the soils. It is quite various as shown in Fig. 8. In the north Japan, the soybean field consisting of volcanic ash soil or diluvial soil keeps generally a high phosphorus absorption coefficient, lacking in cation and holding a high acidity. To such soils, the application of compost, phosphoric acid and lime is very effective. Potash and lime are comparatively effective for granite and alluvial soils. Generally, farmers do not apply so much amount of fertilizer. The standard amount of fertilizer application in experiment stations, to the yield of more than 3 ton/ha is, in the case of volcanic ash soil, N: 30 kg, P_2O_5: 100 kg, K_2O: 80 kg, calcium carbonate: 1 ton, compost: 5–10 ton and in the case of alluvial soil, N: 20 kg, P_2O_5: 50 kg, K_2O: 55 kg, calcium carbonate: 0.5 ton, compost: 5 ton.

5) Farming practices: Soybean farming is differenciated into two patterns: single cropping system and inter-cropping system.

The one adapted in Hokkaido and some other areas depends mainly on tractor or animal power. The other is made of a combination of man power and hand tractor.

3. Problems in the future

The points to regard, in short, about the soybean cultivation in the east Japan are: a) ensuring the number of plants per unit area as planned, b) ensuring the optimum growth amount and c) improving the ratio of seed weight to stem and leaf weight to stem and leaf weight. As shown in Table 2, the average yield of the farmers increases every year as well as that of the experiment stations. These increments of the yield prove the effectiveness of the improvement in the growing technics, which has been carried out in the above ways, as well as the effect of introducing excellent varieties recently bred out. But, as there is still a big difference between the yield of the farm-

Table 2. Average of the maximum yields at various experiments carried out in the fields of Tohoku Agricultural Experiment Station (A), and, average yield of the farmers in Tohoku region (B)

Years	A (t/ha)	B (t/ha)
1955–1959	2.66	1.25
1960–1964	3.67	1.35
1965–1969	4.08	1.36

Table 3. High yielding examples in the cultivation with a big amount of fertilizer application and dense planting

Experiment Station (Year)	Yield of grains (t/ha)	Variety
Miyagi Exp. Sta. (1960)	7.86	Miyagishirome
Iwate Exp. Sta. (1962)	7.65	Tokachinagaha

ers and that of the stations, much efforts should be concentrated to narrow this gap. In the research and experiment, the problem remains in the matter indicated above in the item c). The study on this item will make clear how to approach to the high yield examples (in Table 3).

In addition, the elevation of labor productivity in the inter-cropping areas should be further scrutinized.

Discussion

Arwooth N. L., Thaialnd: Could you explains the relation between the weight of the stems and the yield of soybean?

Answer: There is high correlation between the weight of stems and the yield of soybean when lodging does not occur, because the activity of assimilation and the translocation of assimilation products depend on the size or weight of stems within the limit of optimum leaf area index.

G. W. E. Fernando, Sri Lanka: Soybean has a high nitrogen requirement. Can the nitrogen requirement be met alone by rhizobial inoculation. Is it necessary to add nitrogen fertilizer as a booster dose immediately after the planting?

Answer: In the field where soil productivity is high, we need not to apply the nitrogen fertilizer. But it is necessary to apply nitrogen fertilizer as a booster dose before or immediately after the planting in the northern cooler districts of Japan as well as in the case of the cultivation of earlier maturing varieties.

References

1) Fukui, J. and M. Arai: Ecological studies on Japanese soybean varieties. I Classification of soybean varieties on the basis of the days from germination to blooming and from blooming to ripening with special reference to their geographical differentiation. Jap. J. Breeding 1: 27–39, 1951
2) Furutani, Y.: Soybean cultivation and its improvement in Kyushu district. The Nogyogijutsu, 11, 352–356 (1956). (In Japanese.)
3) Iwate Agr. Exp. Sta.: Studies on the yield increment and fertilizer application of soybean plants. (1964). (In Japanese.)
4) Nishiiri, K., B. Sugimoto, M. Kudo and M. Kinebuchi: Ecological studies on the practical shifting of the cultivation seasons and the productivity of soybean in the cooler regions of Japan. II. Tohoku Agr. Exp. Sta. A prompt report, 5, 53–58 (1962). (In Japanese.)
5) Nozaki, M. and K. Asano: Experimental tests on the single cropping cultivation of soybean. Tohoku Agr. Res., 4, 75–78 (1962). (In Japanese.)
6) Oba, T., I. Katsura, S. Kudo and M. Kinebuchi: Studies on the agronomical problems for favourable growth of soybean plant, I. The growing process of soybean plant on a grower's field with high productivity. Proc. Crop Sci. Soc. Japan, 32: 233–236, 1964.
7) ————: Growth analytical studies on soybean in Tohoku District, I. The comparison of growth on four different soils. Tohoku Agr. Exp. Sta. Kenkyu-sokuho, 5: 47–62, 1965.
8) ————, and T. Okubo: Growth analytical studies on soybean in Tohoku District, II. Effect of temperature on the dry matter production of soybeans planted at various dates on some different soils. Report of the Tohoku Branch, The Crop Science Society of Japan, 11: 63–64, 1969.
9) ————, and T. Okubo: Studies on the agronomical problems for favourable growth of soybean plant.—Optimum plant population and leaf area index on three soil fertilities. Proc. Crop Sci. Soc. Japan, 39, Extra issue 2, 11–12, 1970.

10) Oba, T.: Development of the experimental tests on the cultivation techniques of soybean and its attainable limit. Japan Pulse Fund Society, Pulse Production in Tohoku region, 3, 233–258 (1972). (In Japanese.)
11) Shimano, T., T. Igarashi, H. Kudo and T. Takezaki: Natural environment and pulse production in Kyushu region. Actual conditions on the cultivation of pulse in Kyushu. Japan Pulse Fund Society, Pulse Production in Kyushu region (part I), 43–146 (1971). (In Japanese.)
12) Takemura, T., M. Nozaki, M. Nakamura, H. Kurihara and T. Oba: Varietal growth patterns and planting density of soybeans on different production bases. Tohoku Agr. Res., 10, 177–182 (1968). (In Japanese.)