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超早生型のダイズ遺伝資源に関する生態学的研究

農学専攻博士後期課程

Grzegorz Konieczny

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Ph. D. Thesis

Department of Agronomy

Graduate School of Agriculture

Hokkaido University

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I. Preface

Soybean, Glycine max (L.) Merr., is important supplier of edible oil and high protein food and feed. It is native to Eastern Asia where its cultivation and consumption have a long tradition, more than 4500 years in China (Probst and Judd, 1973). According to Hymowitz (1970) the migration of the soybean from the eastern half of northern China to southern China, Korea, Japan, and southeast Asia probably took place during expansion of the Chou dynasty (ca. eleventh to third century B.C.). In the past, China was the only major producer of soybean. After World War II the USA turned from the importer to the biggest exporter of soybean. Until about fifteen years ago soybean seed production was concentrated in above mentioned two major suppliers (Smith and Huyser, 1987). Both of these countries are suitable for efficient soybean cultivation because they possess vast areas of mild climate in low latitude which imposes relatively short daylength. In recent years, as a world demand for cheap vegetable oil and protein is steadily increasing, more countries are turning their interest into that valuable crop.

There are some trends in the crop production to use cultivars photoperiodically neutral, able to grow well in a wide range of area (latitude). Often such genotypes combine photoneutrality with earliness of maturity. With progress in

the plant breeding and crop management the early genotypes may produce sufficient yield comparing with traditional full season cultivars. They are especially important in the regions with limited length of growing season and may find applications in the areas where more than one crop per season can be cultivated. Along with world wide and northward especially expansion of soybean cultivation, the importance of early and photoperiodically neutral or tolerant genotypes will increase.

With expanding soybean production northward to about 50°N latitude a new type of cultivars appeared on the seed market. Some of them are highly specific: short-season, insensitive to long daylength and low temperatures, lodging resistant, and yielding well in a high plant density. The distinctive feature of the cultivars adapted to production in long daylength conditions is earlier maturity than extremely early maturity cultivars. Their growth type is usually indeterminate, with moderately tall stature and a number of rather short branches. It is so called narrow profile stature due to upright branches. In this dissertation the outlined above type of genotypes, able to grow, ripen and yield successfully in the regions of more than 50°N latitude, may be defined 'super-early'.

In Hokkaido conditions there are early and extremely early cultivars in use. No one of these cultivars matures as early as genotypes designated as super-early.

Turning interest toward more dense planting of super-

early genotypes was inevitable. Since growing conditions in the northern cultivation zone are harsh (e.g. short season), soybean growth is intensively limited. Small plant size suggests that yields could be increased by raising the plant density. To obtain economically justified seed yield soybean should be planted there in higher density than in areas like Japan or south of the USA. Similar tendency to shift from conventional wide to narrower row spacings for maximum seed yields were observed in dry edible bean (Phaseolus vulgaris L.) as was reported by Grafton et al. (1988). Nelson and Weaver (1980) proved that in the high density planting (intrarow space reduced) soybean plants are able to fix enough nitrogen to cover requirements of increased seed yield production.

The recent progress in development of selective herbicides allowed to eliminate mechanical weeding which was a problem in narrow interrow seeding. Moreover, it is possible to reduce costs in the narrow interrow management as compared with wide interrow cultivation systems (Boquet et al., 1982).

In soybean production the major challenge comes from interaction between cultivar and numerous environmental factors. Improved cultivars substantially contributed to increase in soybean yield (Luedders, 1977; Boerma, 1979; Wilcox et al., 1979; Boyer et al., 1980). To exploit fully an available germplasm the new cultivars should be permanently evaluated in different production conditions. With development in breeding and releasing super-early maturing cultivars

they should be tested in high plant density. Super-early genotypes, selected for cultivation in high latitudes, may be alternative to traditional, abundantly growing determinate genotypes in moderate latitudes.

Breeding and releasing a new genotype brings a new problem. It is its interaction or response to additional space given during developmental processes after some hazards have destroyed a number of plants. Ability to compensate lost plants and fill the space given during plant development may be crucial in answering the question: when plants are able to compensate losses to economically justified level and when replanting should be the better choice.

In Japan, determinate growth habit have been prevailing among commercial cultivars (Nagata, 1960, Fukui, 1963 Bernard, 1972). It is expected that super-early genotypes may also be promising in soybean production of Hokkaido. Introduction of a new germplasm requires revision in crop management. Nevertheless, behavior of super-early soybean remains to be elucidated in Hokkaido conditions.

In this study some attempts were made to examine the ecological response of super-early soybean to Hokkaido conditions. The attention was paid on the comparison of super-early genotypes released in Poland with early Japanese cultivars in terms of phenological, morphological, biomass and seed yield characteristics.

In the Chapter IV, the results of comparative examinations of the Polish with super-early and the Japanese with

early maturity genotypes were presented. Detailed examination was carried out in Sapporo and general one in Polish conditions. Other objectives were to survey isoenzyme constitution and cold resistance in juvenile stages.

In the Chapter V, the results of testing the behavior of super-early genotypes in different plant densities when compared with early Japanese cultivars were presented. High plant density was imposed by altering interrow space (intrarow space constant) and separately by altering intrarow space (interrow constant). Interaction of genotype by interrow or intrarow space received special concern.

In the Chapter VI, the results of the response of Polish and Japanese genotypes to additional space created by removing fifty percent of population in different stages of plant development were presented. The examination was focused on stability (compensation ability) of Polish and Japanese genotypes regarding particular characteristics.

On the base of results obtained from the present experiments, possible applications and introduction of super-early cultivars to Hokkaido conditions could be discussed.

II. Review of literature

Egli (1988) noticed that the spatial distribution of plants in a crop community is an important determinant of the yield. However, the mechanisms responsible for the responses to changing plant density are not well understood. In the last two decades the interest in narrow planting arose among soybean researchers and farmers. The subjects and purposes of research were differentiated, and the problem was elucidated from many standpoints.

Following works reported interaction of genotypes with density modified by interrow and intrarow space.

Johnson and Harris (1967) found a positive response of cultivars to narrow interrow space, with stronger reaction of early genotypes in seed yield, plant height, lodging and seed size. The earliest cultivar showed an inverse relationship between seed size and plant density.

Basnet et al. (1974) reported that under irrigated conditions plants in narrow interrow space were taller in stature, lodged more, produced fewer nodes, branches, pods on branches, pods on stem and seeds per plant. Height of the first pod increased as interrow or intrarow space decreased. Interrow and intrarow spaces did not affect weight per seed. The 'cultivar x interrow space' interaction was found in some of characteristics measured (report lacks details). Changing

interrow space itself had no effect on yield, differences occurred when with interrow space the density was changed.

Boquet et al. (1982) detected a 'cultivar x interrow space' interaction for yield. Higher yields occurred when both interrow space and planting date were selected for individual cultivars and locations.

Ablett et al. (1984) found for seed yield both 'genotype x interrow space' and 'genotype x seeding rate' interactions significant. The earliest cultivar showed the greatest seed yield response to narrow rows and higher density.

Walker and Fioritto (1984) examining soybean cultivars regarding maturity, seed yield and apparent harvest index from Maturity Groups II and III in two interrow spaces (densities) found that only for seed yield the 'genotype x interrow space' interaction was significant.

Ethredge et al. (1989) reported a 'genotype x interrow space' interaction for pod number and weight, and seed yield in the experiment with Maturity Group V cultivars subjected to three interrow spaces (densities). The interaction was due to greater response to narrow interrow of short stature, narrow profile (upright branches) cultivar.

Hugie and Orf (1989) examining preliminary breeding materials of early maturity soybean found the 'genotype x interrow space' interaction for seed yield in four of six conducted tests. In the earlier maturity groups, narrow rows were superior or equivalent to wide rows in identifying

genotypes for further testing in either row space.

Hinson and Hanson (1962) found significant 'genotype x intrarow' interaction in seed yield, percent of protein and oil, seed size, plant height and branch number per plant but did not elaborate on tendency of changes.

Ramseur et al. (1984) reported that intrarow space (interrow space constant) had little influence on seed yield of Maturity Group VII cultivar.

Weber et al. (1966), Shannon et al. (1971), and Herbert and Litchfield (1982) found that narrow interrow or intrarow space and more dense plantings were superior to other densities and row widths.

Lehman and Lambert (1960) found heavier weight per seed in 40 inches than in 20 inches interrow space in one location and no tendency in the other. The late cultivar did not respond to interrow space but the early produced some substantial effects.

Wilcox (1974) reported that plant height, basal pod height, and lodging increased with increasing planting density. Mature plant weight and seed weight per plant increased as population density decreased. Maturity date and weight per seed were not affected by changes in density. The greatest response in seed yield associated with interrow space was found in the earliest maturing cross.

Examining semideterminate and indeterminate lines, Green et al. (1977) reported that smaller plants gave greater response to narrow interrow space than taller plants. Seed

size was not affected by interrow space and interaction with genotypes was not detected.

Costa et al. (1980) reported that early genotypes generally exhibited a greater yield response to narrow interrow space than later maturing genotypes, but later ones produced more yield over all interrow and intrarow spaces and years. Later maturing cultivars grew taller and set basal pods higher than early cultivars. 'Genotype x interrow space' interaction was not detected. Increased plant density increased weight per seed.

Hartung et al. (1980) reported a lack of 'genotype x interrow space' interaction in tested isolines with morphology changed by some qualitative genes.

Wilcox (1980) reported that both determinate and indeterminate types responded similarly to plant density, increasing seed yield in more dense planting with narrow interrow space. Except maturity the other characteristics did not show 'genotype x interrow space' interactions.

Parker at al. (1981) using various interrow spaces (constant density) found narrow ones more productive. In the experiment with four cultivars from V to VIII maturity groups no 'genotype x interrow space' interaction was detected.

Beatty et al. (1982) showed that combination of narrow interrow space with higher planting density produced greater yield. The 'cultivar x planting method' (broadcasting and 18, 48, 96 cm interrow space) interaction was not detected.

Weaver and Wilcox (1982) did not find any 'genotype x

interrow space' interaction in 76 cm (25.8 plants/m^2) and 30 cm (32.3 plants/m^2) interrow space for maturity, lodging, plant height and seed yield.

Safo-Kantanka and Lawson (1980) tested two early maturity soybean cultivars in narrow rows (10, 15, 20 and 30 cm) with four rectangularities (1:1, 1:2, 1:3, 1:4) and density ranging from 11 to 400 plants/m^2. They found that significant yield differences were demonstrated by narrowing interrow space but not by changing rectangularity.

In the following reports the combination of high plant density with narrow interrow space affected little or inversely the seed yield when compared with more sparse planting.

Hicks et al. (1969) examined a density response of four plant types: short and tall determinate, narrow and normal leaflet in two genetic backgrounds. Maximum leaf area index was attained earlier when plants were growing in 15 cm interrow space. The height of the short determinate type increased in narrow interrow space more than other types. Interrow space and seeding rate did not affect seed yield. Plants of the short determinate types did not lodge and produced large number of pods near ground surface. Stem diameter decreased when seeding rates increased.

Lueschen and Hicks (1977) reported that in high density the yield increased in one year but not in the others. Plant height and maturity were not affected by interrow space while lodging increased at higher densities. The 'cultivar x intra-

row space' was not found in any of three years.

According to following works the impact of plant density (interrow and intrarow space altered) on seed yield and other characteristics may depend on the date of planting.

Cooper (1971) examining planting date and interrow space association found the 'cultivar x planting date' interaction in seed yield and lodging. Seed yield was unaffected by seeding rate, but tended to be lower where the higher planting density caused severe and early lodging.

Carter and Boerma (1979) found 'genotype x planting date' interaction in seed yield, lodging, flowering date, and plant height. The 'genotype x interrow space' interaction was observed in seed yield and seed size over years. Narrow interrow space increased yields and delayed maturity.

Beaver and Johnson (1981b) found no 'cultivar x planting date x interrow space' interactions for characteristics measured. The seed yields in the northern USA of determinate and indeterminate cultivars increased significantly as interrow spaces were narrowed from 80 to 50, whereas seed yields in 50 cm and 20 cm interrow space did not differ.

Following reports pointed on the role of yield limiting factors in response of genotypes to interrow space and plant density.

Doss and Thurlow (1974) detected 'genotype x interrow space' and 'genotype x plant density x irrigation' interactions for plant height. Plant height was affected by irriga-

tion and plant density but not by interrow space.

Taylor (1980) reported lack of differences in the yield between narrow and wide rows when water supply was limited.

Cooper and Jeffers (1984) supported the hypothesis that any yield limiting factor, such as lodging, moisture stress, nitrogen or other nutrient stress can significantly reduce the soybean yield response to narrow interrow space.

Hoggard et al. (1978) testing determinate cultivars from Maturity Group V (vary in lodging resistance) in different intrarow spaces stated that although the 'genotype x intrarow space' interaction was not significant, there was a trend toward greater yield stability across density as lodging resistance of a cultivar increased.

The row spacing imposes some limitations on the weed control practices. In the narrow interrow spaces, mechanical weed control is difficult and limited to very early stages of plant development.

Cooper (1977) and Wax et al. (1977) reported yield advantage of narrow over wide interrows when herbicides effectively controlled all weeds. Early maturing cultivars were found to be responsive to narrow interrow space with yield advantages as much as 30 to 40% under very high yield, with irrigation. Cultivars interacted with interrow space.

In the soil erosion prone areas, the narrow interrows may be more beneficial in reducing soil-losses than wide interrows. Mannering and Johnson (1969) found that soybean

narrow interrow spaces increased ground cover as early as three to four weeks after planting.

Literature dealing with compensative ability of soybean is not so extensive as that of soybean planting density.

Pandey and Torrie (1973) stated that soybean was able to compensate for differences in plant density. Compensation was accomplished primarily through number of pods per plant.

Stivers and Swearingin (1980) reported that yields of the skip row declined as skips became longer. Relatively small decline in seed yield for longer skips was due to compensation resulting from increases in numbers of branches per plant and increases in yield on them. Increasing weight per seed played a small role in yield compensation. The 'cultivar x space treatment' interaction for seed yield was significant only in one of two years of experiment. The late maturing, full season cultivar had a greater ability to compensate yield for longer skips than a shorter, earlier cultivar.

Pepper and Walker (1988) examined yield compensation abilities of determinate and indeterminate soybean cultivars. The lack of 'cultivar x skip' interaction suggested that compensation for skipped stands was not influenced by the growth habit of the soybean.

Reviewed reports reflected many aspects of plant development as affected by plant density, arrangement and numerous environmental factors. Complexity of the problem was underlined by Duncan (1986) who stated that in spite of more than

50 years of experiments designed to show effect of interrow and intrarow space on soybean yields, no generally accepted theory emerged to explain the results reported.

III. General characterization of materials and methods

It is believed that soybean cultivation in higher latitude than 50°N cannot bring economical returns and is not justified. Super-early genotypes used in present experiments were selected and released in Poland beyond the northernmost limit of soybean cultivation (above 52°N latitude). For that reason they are tolerant or insensitive to long daylength and may yield in Polish conditions above 2000 kg/ha and bring income comparable to other legumes. It was expected that in lower latitudes super-early genotypes might have considerably shorter vegetation period. In the experiments super-early genotypes were compared with Hokkaido cultivars.

1. Genotypes applied

Plant material was selected on the basis of varied maturity, growth habit, hundred seed weight, seed yield, and other characteristics.

General features of experimental materials are presented in the Table III-1. Data are based on observations gathered at locations of selecting and releasing particular genotypes. One of more important characteristics of genotypes used in the northernmost areas of soybean cultivation is their earliness. As it is evident from the Table III-1 the maturity of Polish genotypes was intensively differentiated from Japanese

Table III-1. General characteristics of Polish and Japanese genotypes used in experiments

Genotype and abbreviation		Origin	Growth type [#5]	Harvest maturity [#6]	Seed size [g] [#6]
	[#1]				
AR1	AR1	Bl	Poland[#2]	Dt2	Oct.20	14.7
IHAR-NK	IHA	Bl	Poland[#3]	Dt1	Oct.10	17.7
S23	S23	Bl	Poland[#2]	Dt1	Sept.22	15.1
R18	R18	Bl	Poland[#2]	Dt1	Sept.17	17.4
Polan	POL	Cv	Poland[#3]	dt1	Sept.12	12.4
Progres	PRO	Cv	Poland[#3]	dt1	Sept.06	14.9
Kitahomare	KHO	Cv	Japan[#4]	dt1	Oct.05	30.4
Kitamishiro	KMI	Cv	Japan[#4]	dt1	Sept.30	25.2
Okuhara	OKU	Cv	Japan[#4]	dt1	Sept.17	28.1
Suzuhime	SHI	Cv	Japan[#4]	dt1	Sept.29	12.8
Toyosuzu	TOS	Cv	Japan[#4]	dt1	Oct.01	31.1
Wasekogane	WKO	Cv	Japan[#4]	Dt2	Sept.30	19.4

[#1] Bl: breeding line, Cv: cultivar
[#2] Academy of Agriculture, Poznan, Poland
[#3] Plant Breeding and Acclimatization Institute, Radzikow, Poland
[#4] Tokachi Agricultural Experimental Station, Hokkaido, Japan
[#5] dt1: determinate, Dt2: semideterminate, Dt1: indeterminate
[#6] data from location of origin

cultivars. These high differences of super-early genotypes occurred in the long daylength environment characteristic to Polish conditions. The earliest cultivars were both determinate types. The latest genotype 'AR1' had semideterminate growth habit. It is worth to notice that in Polish circumstances only genotypes maturing before the end of September are able to ripen and dry in the field fully. 'Wasekogane' and 'Suzuhime' were narrow leaflet, white pubescent genotypes. Other genotypes had oval leaflets and brown pubescent. Visual observation indicated that leaflets of Polish genotypes were smaller than those of Japanese cultivars. Flowers of 'Polan' and 'Kitamishiro' were white, and of the other genotypes purple. Pods of 'AR1' were dark brown, of 'Suzuhime', 'Toyosuzu' and 'Wasekogane' light brown, and of the other brown. 'Toyosuzu' and 'Wasekogane' produced sphere and other genotypes ellipsoidal seeds. 'Progres', 'Suzuhime' and 'Wasekogane' had seeds yellow, 'Polan' yellow with light olive saddle pattern, and the other had seeds yellow-white. Hilum of 'Polan' was black, of 'Kitahomare', 'Kitamishiro' and 'Okuhara' dark brown, of 'Suzuhime' and 'Wasekogane' yellow and of the others brown.

2. Outline of experiments

Most of experiments were carried out on the field of Experimental Farm, Faculty of Agriculture, Hokkaido University, Sapporo, Japan. Conventional cultural practices with chemical insect control were applied. Artificial compound

fertilizer was applied before preplant cultivation in the dose of N - 34, P - 110, K - 85 and Mg - 25 kg/ha. Sowing was done manually on the depth of about 2.5 cm. Weeding was manual, according to the needs of particular experiments and plots were kept weed free throughout the season. Phenological characteristics were recorded on the plot basis. Stages of soybean plant development were recorded accordingly to description of Fehr et al. (1971). All weight recordings were done on air dry planting material.

3. List and description of characteristics examined

Phenological characteristics

Beginning of flowering - number of days from planting to 'R-1' stage of plant development.

Duration of flowering - number of days from 'R-1' to 'R-2' stage of plant development.

End of flowering - number of days from planting to 'R-2' stage of plant development.

Harvest maturity - number of days from planting to 'R-8' stage of plant development.

Canopy closure - days from planting to covering interrow space.

Morphological characteristics

Plant height - distance from the soil to the top of a plant [cm].

Stem node number - number of nodes on main stem.

Branch number - number of first order branches.

Stem diameter - diameter of main stem measured at soil surface [mm].

Lodging score - five grade score: 1 - all plants erect, 5 - all plants prostrate.

Basal pod height (harvest space, first or bottom pod height) - distance from the soil surface to the lowest pod [cm].

Basal pod ratio - ratio of above characteristic to plant height [%].

Pod number below 10 cm of plant height - pod number on the bottom part of stature from the soil surface to 10 cm.

Ratio of pod number below 10 cm of plant height - ratio of above characteristic to total pod number per plant [%].

Pod number below 15 cm of plant height - pod number on the bottom part of stature from the soil surface to 15 cm.

Ratio of pod number below 15 cm of plant height - ratio of above characteristic to total pod number per plant [%].

Pod number below half of plant height - pod number on the lower half of plant height.

Ratio of pod number below half of plant height - ratio of above characteristic to total pod number per plant [%].

Above ground biomass and its components

Mature plant weight (biomass) - weight of mature above ground plant part without leaves and petioles [g].

Stem weight - weight of main stem [g].

Ratio of stem weight - ratio of above characteristic to weight of stem plus branches [%].

Branch weight - weight of all branches per plant [g].

Ratio of branch weight - ratio of above characteristic to weight of stem plus branches [%].

Combined stem and branch weight - weight of stem and branches together [g].

Pod weight per plant - all pods per plant weighed after threshing and separating seeds [g].

Pod weight on stem - weight of pod walls on stem, taken after threshing pods and separating seeds [g].

Pod weight on branches - weight of pod walls on branches, taken after threshing pods and separating seeds [g].

Sterile pod weight - weight of all seedless pods [g].

Weight per pod - weight per fertile pod overall the plant taken after threshing pods and separating seeds [mg].

Weight per pod on stem - weight per fertile pod on main stem taken after threshing and separating seeds [mg].

Weight per pod on branches - weight per fertile pod on branches taken after threshing and separating seeds [mg].

Harvest index - ratio of seed yield to mature plant weight without leaves and petioles [%].

Seed yield and its components

Seed yield per plant - weight of total seed yield per plant

[g].

Stem seed yield - weight of seed yield on main stem [g].

Branch seed yield - weight of seed yield on branches [g].

Daily seed yield efficiency (seed yield per day) - seed yield per plant divided by number of days from planting to harvest maturity [mg].

Pod number per plant - pod number on the whole plant.

Pod number on stem - pod number on main stem.

Ratio of pod number on stem - ratio of above characteristic to fertile pod number per plant [%].

Pod number on branches - pod number on all branches together.

Ratio of branch pod number - ratio of above characteristic to fertile pod number per plant [%].

Sterile pod number per plant - number of all sterile pods per plant.

Ratio of sterile pod number - ratio of above characteristic to total pod number per plant [%].

Seed number per plant - total number of seeds per plant.

Stem seed number - number of seeds on main stem.

Branch seed number - number of seeds on branches.

Hundred seed weight - weight of seed yield per plant divided by seed number per plant x100 [g].

Hundred seed weight on stem - weight of seed yield on main stem divided by seed number on main stem x100 [g].

Hundred seed weight on branches - weight of seed yield on branches divided by seed number on branches x100 [g].

Seed number per pod - seed number per plant divided by pod

number per plant.

Seed number per pod on stem - seed number on main stem divided by pod number on main stem.

Seed number per pod on branches - seed number on branches divided by pod number on branches.

IV. Characteristics of Polish and Japanese genotypes

Introduction

When a new germplasm is to be introduced into a given region its response to new environment should be determined. Germplasm Preservation Report of Tokachi Experimental Station (1988) delivered basic characteristics of some super-early genotypes tested in the collection trials at Tokachi, Hokkaido. However, there are no reports studying the details of agronomically important characteristics of super-early genotypes in Hokkaido conditions.

The latitude of Poznan and Warsaw, Poland where super-early genotypes of this study were released is 52°N, and that of Sapporo, Japan is 43°N. This difference was expected to affect some characteristics of genotypes introduced from more northern area to Hokkaido.

The objectives of this chapter were to present the results of examining the features of Japanese early cultivars and Polish super-early genotypes in both Sapporo and Polish conditions through comparing their phenological, morphological, above ground vegetative biomass, seed yield and its components. Another objective was to examine their isoenzyme constitution and cold tolerance in the juvenile stages.

Materials and methods

In the experiments twelve genotypes were applied (six Polish and six Japanese). The Polish genotypes consisted of two cultivars: 'Polan' and 'Progres', and four breeding lines: 'IHAR-NK', 'AR1', 'S23', and 'R18'. The Japanese cultivars consisted of: 'Kitahomare', 'Toyosuzu', 'Suzuhime', 'Kitamishiro', 'Okuhara', and 'Wasekogane'.

Experiment 1

In 1987 an experiment with three replications was applied. Interrow space was 25 cm, intrarow space was 10 cm (density 40 plants/m^2). Plots were 1.5 m wide with rows 1.0 m long. Sowing was done on May 21. At harvest maturity five plants were sampled from every plot for biometrical evaluation.

Experiment 2

For comparing Polish and Japanese genotypes in long daylength conditions a test was carried out at Poznan. Interrows were 50 cm and intrarow spaces were 20 cm. One seed per hill planting was done on May 5, 1988. Measuring was taken from five plants/plot. Agronomically essential traits were recorded. For comparison data from Germplasm Preservation Report of Tokachi Experimental Station (1988) from planting in 60 cm interrow and 10 cm intrarow spaces are presented with data from Polish conditions.

Experiment 3

Horizontal starch gel electrophoresis was carried out on three germinated seeds from every genotype. Seven enzyme systems encoded by 12 loci were used to determine the isoenzyme genotype of each item. Enzyme assayed were aconitase (EC 4.2.1.3, Aco1, Aco2, Aco3, Aco4 loci), acid phosphatase (EC 3.1.3.2, Ap locus), endopeptidase (Enp locus), isocitrate dehydrogenase (EC 1.1.1.42, Idh1 and Idh2 loci), leucine aminopeptidase (EC 3.4.11.1 Lap1 locus), mannose-6-phosphate isomerase (EC 5.3.1.8 Mpi locus) and phosphoglucomutase (EC 2.7.5.1, Pgm1 and Pgm2 loci). Methods for sample preparation and isoenzyme analysis were adapted from Griffin and Palmer (1987), buffer system and isoenzyme assays were taken from Cardy and Beversdorf (1984),

Experiment 4

In 1989, a cold test on Polish and Japanese genotypes was carried out. On April 18, seeds were planted in a greenhouse in excess to the pots of 25 cm diameter and thinned after emerging to five plants per pot. After ten days the seedlings were transferred outdoor and left until May 10. The average daily temperature for this period was 9.3°C. For evaluating genotypes in resistance against low temperature the three grade score was applied; 'tolerant': no chlorotic symptoms visible on seedlings, 'medium': chlorotic spots appeared, 'sensitive': leaves apparently chlorotic.

Results

Experiment 1

Polish cultivars 'Polan' and 'Progres' (both determinate) began to flower earlier than 'AR1' and completed to flower earlier than the other Polish genotypes and all Japanese cultivars. 'IHAR-NK', 'S23' and 'R18' began to flower early but due to longer duration of flowering they completed to flower around the time of Japanese cultivars. On the average, the flowering of determinate genotypes was shorter than those of semideterminate and indeterminate genotypes. Polish breeding lines as indeterminate and semideterminate types began to flower earlier but completed flowering nearly as late as Japanese ones which all but 'Wasekogane' were determinate (Table IV-1). Very early flowering genotypes turned to be very early maturing. Polish genotypes were about one month earlier in maturity than Japanese cultivars (Table IV-1). The heritability of phenological characteristics except the harvest maturity of Japanese cultivars was very high (Table IV-1).

Plant height was greatly different among genotypes (Table IV-2). On the average, the Polish genotypes were about ten centimeters shorter than Japanese cultivars. The height of 'Toyosuzu' and 'Suzuhime' was below the average of Polish genotypes. The Polish cultivar 'Progres' was the shortest, and 'Kitahomare' and 'Kitamishiro' were the tallest (Table

Table IV-1. Phenological characteristics, canopy closure and heritability (h^2) of Polish and Japanese genotypes in Sapporo, 1987

Genotypes	Flowering			Harvest maturity	Canopy closure
	beginning	duration	end		
Polish					
AR1	50.0	15.3	65.3	122.3	35.3
IHA	45.0	26.0	71.0	113.3	36.3
S23	45.0	19.7	64.7	113.3	36.3
R18	44.0	27.0	71.0	113.0	36.0
POL	43.7	11.7	55.3	112.3	37.3
PRO	44.7	11.0	55.7	108.7	36.3
Mean	45.4	18.4	63.8	113.8	36.3
h^2	0.82	0.97	0.99	0.88	0.07
Japanese					
KHO	58.0	7.0	65.0	146.3	35.3
TOS	53.7	9.0	62.7	148.7	37.7
SHI	60.3	10.3	70.7	150.0	38.3
KMI	59.7	8.0	67.7	151.3	33.7
OKU	53.7	9.7	63.3	142.0	34.7
WKO	53.0	21.3	74.3	137.0	36.3
Mean	56.4	5.4	67.3	145.9	36.0
h^2	0.88	0.94	0.98	0.69	0.38
LSD 5%	1.6	1.6	0.7	2.4	ns*

Note:
* ns nonsignificant

Table IV-2. Plant height, branch number, stem diameter, lodging score, basal pod height and heritability (h^2) of Polish and Japanese genotypes in Sapporo, 1987

Genotypes	Plant height	Branch number	Stem diameter	Lodging score	Basal pod height	Basal pod ratio
Polish						
AR1	84.7	3.2	6.0	3.2	6.3	7.5
IHA	91.0	3.2	5.8	2.5	9.1	10.0
S23	74.4	3.5	4.7	3.5	4.8	6.5
R18	83.9	4.1	4.9	1.9	6.3	7.5
POL	77.2	3.1	5.7	2.2	3.5	4.6
PRO	60.8	3.4	4.9	2.2	8.9	14.6
Mean	78.7	3.4	5.3	2.6	6.5	8.4
h^2	0.93	0.11	0.52	0.37	0.89	0.93
Japanese						
KHO	104.1	1.7	7.2	3.2	20.3	19.5
TOS	66.7	2.1	6.7	3.5	16.4	24.7
SHI	71.9	1.1	6.2	1.2	14.1	19.6
KMI	103.8	2.1	8.2	3.5	24.0	23.2
OKU	92.4	2.6	7.0	4.2	19.5	21.1
WKO	92.6	1.7	7.6	1.2	10.4	11.2
Mean	88.6	1.9	7.2	2.8	17.4	19.9
h^2	0.97	0.41	0.73	0.71	0.90	0.82
LSD 5%	4.2	0.8	0.7	1.0	1.2	1.5

IV-2).

Japanese cultivars produced less than three and Polish genotypes produced more than three branches per plant (Table IV-2). Exceptional branching ability was observed in the Polish breeding line 'R18'. The smallest number of branches was observed in 'Suzuhime'.

In spite of thin stems the Polish genotypes were slightly more resistant to lodging than Japanese cultivars, which had the stem diameter thick (Table IV-2). 'Kitamishiro' and 'Okuhara' developed the most thick stems but their lodging score was the highest among genotypes.

Heritability in the morphological characteristics was differentiated (Table IV-2). Generally, except ratio of basal pod height the heritability for Japanese cultivars was higher than that of Polish genotypes. Plant height had great and branch number (especially of Polish genotypes) had low heritability.

On the average, the basal pod of Japanese cultivars was almost three times higher than that of Polish genotypes (Table IV-2). When the basal pod height was expressed in the percent of plant height, 'Toyosuzu' had almost one fourth of stature length (bottom part) as nonproductive. Polish genotypes set basal pod low with the lowest in 'Polan'. The basal pod heights of 'Suzuhime', 'Wasekogane' and 'IHAR-NK' were the most desirable among genotypes tested (Table IV-2).

In both spaces from the soil surface up to 10 cm and from the soil surface up to 15 cm, Polish genotypes produced

substantial number of pods and Japanese cultivars did inconsiderably. 'AR1', 'Polan' and 'Progres' developed the greatest pod number below 10 cm and 'S23' below 15 cm (Table IV-3). On the average, except 'Polan' the Polish genotypes produced more than 50% and except 'Wasekogane' the Japanese cultivars produced less than 40% of pods on lower half of stature (Table IV-3). The heritability of basal pod height and number of pods on bottom parts of canopy oscillated from 0.48 to 0.93 (Tables IV-2 and IV-3).

In mature plant weight, 'AR1', 'Kitahomare', 'Wasekogane' and 'S23' were productive and on the other hand 'Suzuhime' was the poorest in biomass. Stem weight of the Japanese cultivars and branch weight of the Polish genotypes were heavy. 'Wasekogane' was distinctive with its very high ratio of stem weight because its branches were the lightest. Branch weight of 'R18' was the heaviest. Combined stem and branch weight of Polish genotypes was relatively smaller than that of Japanese cultivars (Table IV-4). In mature plant weight and its components the heritability was various (Table IV-4).

Threshed pod weight per plant, on stem, and on branches showed high variation in both groups of genotypes, but their means were similar each other (Table IV-5). 'Kitahomare' and 'S23' produced the highest pod weight per plant, 'Okuhara' the smallest. In pod weight on stem and on branches relations were various. 'Kitahomare' 'Wasekogane' and 'AR1' produced the greatest and 'Okuhara' and 'Toyosuzu' the smallest weight of pods on stem. In pod weight on branches, the greatest

Table IV-3. Pod number below 10 cm, 15 cm, and a half of plant height, their ratios and heritability (h^2) of Polish and Japanese genotypes in Sapporo, 1987

Genotypes	Pod number below					
	10 cm	ratio	15 cm	ratio	half*	ratio
Polish						
AR1	4.3	9.1	8.1	17.4	25.5	54.7
IHA	0.9	2.8	4.1	12.5	23.9	73.9
S23	3.2	8.1	9.9	25.3	33.5	85.8
R18	3.2	9.1	7.9	22.3	23.4	67.3
POL	3.7	12.4	6.7	22.5	14.7	49.4
PRO	3.7	10.8	8.7	25.1	18.9	55.3
Mean	3.2	8.7	7.6	20.9	23.3	64.4
h^2	0.87	0.90	0.71	0.70	0.90	0.68
Japanese						
KHO	0.2	0.6	0.2	0.6	13.7	38.4
TOS	0.3	1.1	0.2	0.9	9.1	39.3
SHI	0.2	0.4	1.5	3.2	14.7	31.4
KMI	0.2	0.7	0.2	0.7	10.3	37.8
OKU	0.2	0.7	0.2	0.7	8.9	32.6
WKO	0.7	2.4	1.7	6.3	13.9	50.4
Mean	0.3	0.5	0.7	1.0	11.8	38.2
h^2	0.66	0.69	0.86	0.85	0.71	0.48
LSD 5%	0.7	1.7	1.8	4.7	3.1	13.5

Note:
* of plant height

Table IV-4. Mature plant weight, its components with ratios, and heritability (h^2) of Polish and Japanese genotypes in Sapporo, 1987

Genotypes	Mature weight					
	plant	stem	stem ratio	branches	branch ratio	stem and branches
Polish						
AR1	31.1	5.7	74.7	1.9	25.3	7.7
IHA	25.0	5.4	81.5	1.2	18.5	6.6
S23	28.1	3.6	73.5	1.3	26.5	4.9
R18	25.2	4.2	67.7	2.0	32.3	6.2
POL	24.4	3.8	71.7	1.5	28.3	5.4
PRO	24.8	2.9	64.0	1.6	36.0	4.5
Mean	26.4	4.3	72.2	1.6	27.8	5.9
h^2	0.56	0.93	0.61	0.42	0.61	0.88
Japanese						
KHO	29.2	7.7	89.7	0.9	10.3	8.6
TOS	25.8	5.7	80.1	1.4	19.9	7.2
SHI	22.3	5.0	79.8	1.3	20.2	6.3
KMI	25.6	8.2	84.6	1.5	15.4	9.6
OKU	25.5	5.7	80.3	1.4	19.7	7.1
WKO	29.1	8.8	93.6	0.6	6.4	9.4
Mean	26.2	6.9	84.6	1.2	15.4	8.0
h^2	0.52	0.79	0.87	0.59	0.87	0.64
LSD 5%	3.3	0.9	5.5	0.5	5.5	1.1

Table IV-5. Threshed pod weight per plant, on stem, on branches, sterile pod weight, weight per pod, harvest index and heritability (h^2) of Polish and Japanese genotypes in Sapporo, 1987

Genotypes	Pod weight per plant	Pod weight on branches		Weight per pod	Harvest index [%]
		stem	sterile		
Polish					
AR1	5.8	4.1	1.5	0.2	120	56.7
IHA	5.3	3.8	1.3	0.2	157	52.4
S23	6.0	3.3	2.3	0.4	145	61.2
R18	4.7	3.0	1.4	0.3	123	56.6
POL	4.7	3.0	1.5	0.2	150	58.6
PRO	5.4	3.5	1.7	0.2	150	60.1
Mean	5.4	3.5	1.6	0.3	141	57.6
h^2	0.07	0.04	0.58	0.61	0.37	0.67
Japanese						
KHO	7.3	4.5	2.0	0.8	180	45.6
TOS	5.3	2.9	2.1	0.3	210	51.9
SHI	4.8	3.4	1.1	0.3	97	50.5
KMI	4.7	3.0	1.3	0.4	156	44.2
OKU	4.4	2.6	1.5	0.3	152	55.0
WKO	5.0	4.4	0.5	0.1	178	50.4
Mean	5.2	3.5	1.4	0.3	162	49.6
h^2	0.69	0.76	0.89	0.65	0.91	0.81
LSD 5%	1.2	1.0	0.4	0.2	23	3.3

weight was observed in 'S23' and the smallest in 'Wasekogane' (Table IV-5).

On the average, except 'Suzuhime' weight per threshed pod of Japanese cultivars was greater than that of Polish genotypes. The heaviest weight per pod was produced by 'Toyosuzu', and it was more than two times heavier than weight per pod of 'Suzuhime' (Table IV-5). Regarding threshed pod weight, the heritability observed in the Polish genotypes was lower than in Japanese cultivars, exceptionally low was in pod weight per plant and on stem (Table IV-5).

In harvest index, Japanese cultivars were low. Polish genotypes were high, with distinctively great harvest index of 'S23', 'Progres' and 'Polan' (Table IV-5). Heritability of Polish genotypes was lower than of Japanese cultivars.

Genotypes were various regarding pod number per plant, on stem and on branches and ratios of pods on stem and branches (Table IV-6). On the average, the Polish genotypes produced more pods than Japanese cultivars. 'Wasekogane' produced the greatest rate of pods on stem. 'Toyosuzu' and 'Okuhara' produced the greatest rate of pods on branches. 'Wasekogane' produced distinctively small number of sterile pods. 'Kitahomare' and 'S23' produced the greatest number and ratio of sterile pods per plant among the Japanese and Polish genotypes, respectively (Table IV-6). The heritability of pod number was greater in the Japanese than Polish genotypes (Table IV-6).

On the average, the Polish genotypes yielded higher than

Table IV-6. Pod number, its components with ratios, and heritability (h^2) of Polish and Japanese genotypes in Sapporo, 1987

Genotypes	Pod number						
	plant	stem	%#1	branches	%#1	sterile	%#2
Polish							
AR1	50.5	32.4	69.7	14.1	30.3	4.0	8.0
IHA	35.3	23.3	72.1	9.0	27.9	2.9	8.3
S23	45.3	24.6	62.7	14.6	37.3	6.1	13.5
R18	40.5	21.3	60.7	13.9	39.3	5.3	13.3
POL	33.7	19.3	64.1	10.8	35.9	3.6	10.8
PRO	36.7	20.9	60.2	13.9	39.8	1.8	5.0
Mean	40.3	23.6	64.9	12.7	35.1	4.0	9.8
h^2	0.71	0.72	0.76	0.50	0.76	0.85	0.71
Japanese							
KHO	42.9	23.7	66.1	12.2	33.9	6.9	16.2
TOS	25.9	13.1	55.3	10.5	44.7	2.3	8.8
SHI	49.0	34.8	74.4	12.0	25.6	2.3	4.6
KMI	32.2	18.2	66.6	9.2	33.4	4.8	14.8
OKU	30.9	15.3	56.1	11.9	43.9	3.8	12.3
WKO	28.3	24.6	88.9	3.1	11.1	0.6	2.1
Mean	34.8	21.6	67.9	9.8	32.2	3.4	9.8
h^2	0.94	0.96	0.82	0.88	0.93	0.95	0.96
LSD 5%	5.0	3.5	5.0	2.6	5.0	1.0	2.8

Notes:
#1 percent of overall fertile pod number
#2 percent of total pod number

Japanese cultivars (Table IV-7). 'AR1' and 'S23' yielded higher, and 'Suzuhime' and' Kitamishiro' yielded less than other genotypes which did similarly.

Daily seed yield efficiency of Polish genotypes was markedly greater than that of Japanese cultivars (Table IV-7). 'IHAR-NK' which had the least daily efficiency among Polish genotypes showed greater efficiency than most of Japanese cultivars. 'AR1' produced not only the highest yield but its daily seed efficiency was the greatest as well (Table IV-7).

Except 'Suzuhime' the Japanese cultivars produced less seeds per plant than Polish genotypes. Seeds of 'Suzuhime' were very small and other Japanese cultivars produced larger seeds than Polish genotypes (Table IV-7). The large seeded genotypes like 'Okuhara', 'Toyosuzu', 'Kitahomare' and 'IHAR-NK' produced small number of seeds per plant and per pod. In contrast, the small seeded genotypes like 'Suzuhime', 'AR1', 'S23' and 'Polan' produced greater number of seeds per plant and per pod (Table IV-7).

The heritability of seed yield and its daily efficiency, seed number per plant, hundred seed weight, and seed number per pod of Polish genotypes was smaller than that of Japanese cultivars (Table IV-7). Distinctively small heritability was observed in daily seed yield efficiency of Polish genotypes.

Table IV-7. Seed yield and its daily efficiency, seed number per plant, hundred seed weight, seed number per pod and heritability (h^2) of Polish and Japanese genotypes in Sapporo, 1987

Genotypes	Yield		Seed number /plant	100 seed weight	Seed number /pod
	plant	day			
Polish					
AR1	17.7	144	106.5	16.7	2.3
IHA	13.1	115	50.7	25.9	1.6
S23	17.2	152	102.3	16.8	2.6
R18	14.3	126	80.9	17.7	2.3
POL	14.3	127	76.7	18.6	2.6
PRO	14.9	137	74.9	19.9	2.2
Mean	15.2	134	82.0	19.3	2.3
h^2	0.53	0.38	0.79	0.84	0.62
Japanese					
KHO	13.3	91	47.9	27.8	1.3
TOS	13.3	90	46.1	29.0	2.0
SHI	11.2	75	98.8	11.5	2.1
KMI	11.3	75	46.8	24.9	1.7
OKU	14.0	99	46.9	30.0	1.7
WKO	14.7	107	70.4	20.9	2.5
Mean	13.0	88	59.3	24.0	1.8
h^2	0.64	0.72	0.88	0.93	0.69
LSD 5%	2.0	17	14.5	2.6	0.4

Experiment 2

Regarding phenological characteristics, all Polish genotypes attained to the flowering earlier in the Polish than in Hokkaido conditions (Table IV-8). Japanese cultivars responded in specific way. 'Kitahomare', 'Kitamishiro' and 'Wasekogane' began to flower earlier in the Polish than Japanese conditions. 'Okuhara' and 'Toyosuzu' did not change beginning of flowering in the both environments. 'Suzuhime' began to flower in Poland later than in Hokkaido conditions. In the harvest maturity, Polish and Japanese genotypes responded to daylength conditions in different way. 'AR1' which is late in Polish conditions turned to be very early in Hokkaido. 'R18' showed a reverse reaction to changed environments and was later in Hokkaido than in Poland. 'Progres and 'S23' in both conditions matured after the same number of days after planting. Japanese cultivars substantially extended their vegetation period in Polish conditions. Exceptionally long delaying of maturity was observed in 'Suzuhime' and 'Toyosuzu' (Table IV-8).

In plant height, except 'R18' the Polish genotypes in Polish conditions produced taller plants than in Hokkaido conditions. Japanese cultivars responded to environments specifically. 'Kitahomare', 'Kitamishiro' and 'Wasekogane' grew taller in Hokkaido than in Polish conditions. 'Toyosuzu' grew taller in Polish than in Hokkaido conditions. Plant height of 'Suzuhime' was not affected. In branch number, except 'Suzuhime', the plants were more productive in the

Table IV-8. Phenological and morphological characteristics of Polish and Japanese genotypes in Poland and Hokkaido, 1988

Genotype	Beginning of flowering		Harvest maturity		Plant height		Branch number	
	Pl*1	Ho	Pl	Ho	Pl	Ho	Pl	Ho
Polish								
AR1	59	61	151	126	56	49	6.8	2.5
S23	53	57	122	122	57	47	5.0	2.8
R18	49	55	112	122	38	48	3.8	2.3
PRO	50	54	114	114	43	37	3.4	1.5
Japanese								
KHO	62	66	162	138	51	59	6.2	2.8
TOS	64	64	176	135	50	42	6.0	2.0
SHI	73	70	180	132	51	51	4.4	2.6
KMI	62	68	163	134	45	53	5.2	4.0
OKU	59	59	149	121	45	45	4.8	2.0
WKO	59	61	166	134	61	69	5.0	2.6

Note:

*1 Pl: Polish, Ho: Hokkaido environment

Polish than in Hokkaido conditions (Table IV-8).

Except 'Suzuhime' the genotypes produced more pods and higher yield in the Polish than Hokkaido conditions. Results of 'AR1' were especially spectacular (Table IV-8). The yield of 'Wasekogane' did not increase much in Polish conditions. Some genotypes tended to produce larger seeds in the Hokkaido conditions. Plants in the Hokkaido environment produced more seeds per pod (Table IV-9).

Experiment 3

Results of starch gel electrophoresis were shown in Table IV-10. No polymorphism was detected in aconitase-2 and -3, leucine aminopeptidase-1 and phosphoglucomutase-2 loci. Polymorphism was found regarding aconitase-1 and -4, acid phosphatase, endopeptidase, isocitrate dehydrogenase-1 and -2, mannose-6-phosphate isomerase and phosphoglucomutase-1 loci. The 'b' mobility variant of Aco-1 was found in 'Polan', 'AR1', 'Progres' and the cultivars from Hokkaido except 'Suzuhime' and 'Wasekogane'. Mobility variant 'c' of Aco-4 was detected only in 'IHAR-NK' and 'Progres'. The mobility variants, 'a' of Ap and 'b' of Ep were found only in 'R18'; the latter was also detected in 'Suzuhime' and 'Wasekogane'. The 'b' of Idh-1 was found in 'IHAR-NK', 'R18' and 'Progres'. Mobility variant 'c' of Mpi was found only in 'Toyosuzu'. The mobility variant 'a' of Pgm-1 was found in all Polish genotypes, and also in 'Toyosuzu' and 'Suzuhime' (Table IV-10).

Table IV-9. Seed yield and its components of Polish and Japanese genotypes in Poland and Hokkaido, 1988

Genotype	Pod number per plant		Seed yield per plant		100 seed weight		Seed number per pod	
	Pl*1	Ho	Pl	Ho	Pl	Ho	Pl	Ho*2
Polish								
ARl	149.8	52.8	42.9	15.0	17.2	16.6	1.67	2.25
S23	95.2	37.9	24.2	13.0	14.9	15.8	1.71	2.14
R18	63.2	36.6	17.2	11.9	16.1	17.4	1.69	1.89
PRO	56.8	28.5	17.2	10.5	16.9	18.6	1.79	2.30
Japanese								
KHO	67.4	39.3	33.5	22.2	31.5	30.4	1.58	1.94
TOS	42.6	25.4	21.3	14.5	30.0	31.1	1.66	2.04
SHI	29.8	37.3	5.8	11.1	13.9	12.8	1.39	2.07
KMI	57.2	37.5	26.6	17.3	28.1	25.2	1.66	1.86
OKU	39.6	25.2	19.2	12.2	31.1	28.1	1.56	1.97
WKO	44.0	36.5	14.3	13.5	17.9	19.4	1.81	1.88

Notes:

*1 Pl: Polish, Ho: Hokkaido environment

*2 data taken from other experiment

Table IV-10. Isoenzyme analysis of Polish and Japanese genotypes

Genotype	Aconitase						Idh		Lap		Pgm	
	1	2	3	4	Ap	Ep	1	2	1	Mpi	1	2
Polish												
ARl	b*	b	a	b	b	a	a	a	b	b	a	b
IHA	a	b	a	c	b	a	b	a	b	b	a	b
S23	a	b	a	b	b	a	a	a	b	b	a	b
R18	a	b	a	b	a	b	b	a	b	b	a	b
POL	b	b	a	b	b	a	a	a	b	b	a	b
PRO	b	b	a	c	b	a	b	a	b	b	a	b
Japanese												
KHO	b	b	a	b	b	a	a	a	b	b	a	b
TOS	b	b	a	b	b	a	a	b	b	c	b	b
SHI	a	b	a	b	b	b	a	b	b	b	b	b
KMI	b	b	a	b	b	a	a	a	b	b	a	b
OKU	b	b	a	b	b	a	a	a	b	b	a	b
WKO	a	b	a	b	b	b	a	b	b	b	a	b
	Frequency in 148 Japanese cultivars (x1000)											
a	905	014	993	128	139	649	797	748	-	-	247	-
b	095	986	007	872	861	351	203	252	1000	619	753	1000
c	-	-	-	-	-	-	-	-	-	381	-	-

Notes:

Ap - Acid phosphatase
Ep - Endopeptidase
Idh - Isocitrate dehydrogenase
Lap - Leucine aminopeptidase
Mpi - Mannose-6-phosphate isomerase
Pgm - Phosphoglucomutase
* mobility variants

Experiment 4

In the cold test at juvenile stage of growth, 'S23' and 'Suzuhime' were sensitive, 'IHAR-NK' and 'Polan' were tolerant, and other genotypes were moderately resistant against the low temperature (Table IV-11).

Table IV-11. Outdoor cold test of Polish and Japanese, genotypes in Sapporo conditions, 1989

Genotype	Sensitivity*
Polish	
ARl	medium
IHA	tolerant
S23	sensitive
R18	medium
POL	tolerant
PRO	medium
Japanese	
KHO	medium
TOS	medium
SHI	sensitive
KMI	medium
OKU	medium
WKO	medium

* tolerant - no chlorosis symptoms
medium - chlorotic spots appeared
sensitive - leaves chlorotic

Discussion

Phenological data showed that some genotypes began to flower in Poland earlier than in Hokkaido. This phenomenon can be explained on the basis of different planting time. In Polish conditions soybean was planted on May 5 and in Hokkaido about two weeks later. In that period in Polish conditions the daylength is relatively short and elongates toward summer solstice. The reaction to the daylength after emerging in both environments might cause such plant response.

Long daylength in the period of flowering may cause the delaying of maturity. The long daylength in Polish conditions influenced strongly on all Japanese genotypes because after beginning of flowering the daylength was considerably longer as compared with Hokkaido conditions. 'Progres' and 'S23' seems to be highly insensitive to daylength, since their maturities showed no difference between both environments. All early Japanese cultivars seemed to be more or less sensitive to long daylength. In spite of very long vegetation in Polish conditions, 'Suzuhime' (latest in Poland) and 'Okuhara' (earliest of Japanese cultivars in Poland) did not change their plant height. It is evident that the super-early maturing soybean genotypes began to flower earlier than the late ones. This is consistent with findings of Jaranowski et al. (1983). That is, there is a positive correlation between days from planting to flowering and maturity. The duration and

time of completing of flowering had little or no influence on maturity. For example, the duration of flowering was short in 'Suzuhime' (ten days) although it matured as one of the latest genotypes. It seems that the duration of flowering might be more closely associated with the type of growth rather than with maturity. Determinate type could possess a shorter flowering period than semideterminate and indeterminate types.

Most of the super-early genotypes had relatively short stature as was apparent in the present experiments. Plant height is positively correlated with basal pod height (Jaranowski et al., 1983). The basal pod height not only contributed to the distribution of pods on plant but indicated potential losses of seed yield during combine-harvesting as well. Therefore the number, especially the percent of pods produced in 0-10 cm space above soil surface has an economical importance. It seems that the improving of pod distribution throughout the canopy (shifting up) of Polish genotypes could increase their yielding potential. 'Kitamishiro' had distinctively highest basal pod, it produced most of its pods on the upper half of the stature and yielded low. The excessive harvest space could be also detrimental to yield potential due to the nonproductive substantial part of the stature as it was observed in 'Kitamishiro'. Japanese cultivars set their basal pods relatively high and for this reason produced only a few pods in the bottom parts of stature. Basal pod height depends heavily on the population density and planting

geometry. It is evident that regarding pod distribution the Japanese cultivars were more sensitive to planting density of 40 plants/m^2 than Polish genotypes. From this standpoint the Japanese cultivars carry valuable genes which should be transferred to Polish genotypes to improve their qualities.

Lodging resistance is of interest because of its possible association with seed yield, combine-harvesting loses, and aesthetical value to farmers (Leffel, 1961). In spite of thinner stem diameter and bearing greater seed yield per plant, the Polish genotypes showed little lower lodging score than Japanese cultivars. Selected out and habitually cultivated in the higher densities and having shorter stature, the Polish genotypes revealed their good fitting to the relatively high density.

In general terms, the Polish genotypes performed better in densities applied than Japanese ones did. The seed yield per plant and its daily rate pointed out that earlier maturing genotypes produced grain more abundantly and efficiently than later maturing ones. It seems to be associated with higher harvest index of super-early maturing genotypes. 'AR1' and 'S23' with exceptionally high seed yields and daily seed efficiency appeared to be promising genotypes, although their harvest space and lodging resistance need to be improved.

It seems that the expanded vegetation period in Polish conditions had some positive effects on soybean like greater pod number, seed yield and also in some cultivars larger seeds. Hokkaido conditions were favorable for producing more

seeds per pod. This effect probably is associated with higher temperature during flowering as compared with Polish conditions, where the weather during the flowering time change often.

Isoenzymes can be used for cultivar identification, in plant breeding or tissue culture, in genetic linkage as genetic markers, and in evolutionary studies (Palmer and Kilen, 1987). Mobility variants 'b' of Idh2 were detected in 'Toyosuzu', 'Suzuhime' and 'Wasekogane'. These three genotypes showed the greatest delaying of maturity in Polish conditions. It is probable that this mobility variant has some association with daylength sensitivity. The mobility variant 'c' of Aco4 was found in Polish genotypes but not in any of 148 Japanese cultivars. It proved that some of Polish genotypes possess very distinctive germplasm.

The cold test showed that 'Polan' and 'IHAR-NK' carry a resistance to low temperature in juvenile stages of growth. They may be the source of germplasm in breeding against cold stress in juvenile stages of growth. Such plants could be planted earlier in the spring thus extending growing period and due to this could grow in the shorter daylength before flowering.

From the data delivered in this study, it is evident that super-early genotypes planted in proper density and pattern may yield well and be useful in the Hokkaido environments. Both Polish and Japanese genotypes have strong and weak points. Fortunately, the virtues are complementary and

might be promising when hybridized for obtaining recombinants.

V. Response to various planting densities

1. Introduction

One of the distinctive characteristics of soybean is the tremendous ability to adjust its growth to the space. Therefore most of the important agronomic characteristics are strongly influenced by plant density.

For the optimal seed yield production the range of plant density should be considered. Planting parameters depend on genotype properties such as plant growth type (determinate or indeterminate), branching potential, basal pod height, lodging resistance, etc. Moreover, some environmental factors viz. planting date, water supply, weed control and so on, impose limitations on applied plant density, e.g. interrow and intrarow space.

The interrow and intrarow spaces modify the rate of photosynthetically active radiation intercepted by growing plants. The rate of intercepted radiation can be affected particularly in the early stages of plant growth before the field area is entirely covered by leaves and a fraction of the radiation can be assimilated by plants. In some conditions the light intercepted by plant canopy can be limiting factor in the yield production.

In the traditional cultivating systems soybean is plant-

ed in the wide interrow space 60 to 100 cm. Doss and Thurlow (1974) stated that in general, with shorter growing season, interrow spaces narrower than the conventional 90 to 100 cm result in high yields. Carter and Hartwig (1963) noticed that results from intrarow plant space rates are in general similar for all production areas and rates of 20 to 40 viable seeds/m^2 usually give most satisfactory results in 90 to 100 cm interrow space. Hugie and Orf (1989) stated that recommended seeding rates for indeterminate cultivars in Minnesota (USA) are 36 viable seeds/m^2 for the wide interrow space (76 cm) and 50 seeds/m^2 for the narrow interrow space (25 cm). According to Johnson (1987) rates of 35 to 50 plants per m^2 are generally sufficient to maximize yield, reduce potential harvest losses due to basal pod height and insure adequate stands in unfavorable germinating conditions. It is well documented that such planting rates did not produce optimal yields in the northernmost parts of soybean production area (Weber et al., 1966; Cooper, 1977; Costa et al., 1980; Safo-Kantanka and Lawson, 1980; Beaver and Johnson, 1981a; Beatty et al., 1982). Carter and Hartwig (1963) concluded that length of growing season, growth type of cultivars and fertility level of the soil significantly affected optimum interrow space for a given area and the narrower rows were generally better for the northernmost regions.

The purpose of this chapter was to present the results of the response of super-early genotypes to the interrow and intrarow space when compared with early genotypes. Phenologi-

cal and morphological characteristics, biomass, seed yield and its components of several super-early (Polish) and early (Japanese) genotypes were considered.

2. Response to interrow space (intrarow space constant)

i. Materials and methods

Twelve genotypes were applied. The Polish group consisted of two cultivars: 'Polan' and 'Progres', and four breeding lines: 'IHAR-NK', 'AR1', 'S23' and 'R18'. The Japanese group consisted of six cultivars: 'Kitahomare', 'Toyosuzu', 'Suzuhime', 'Kitamishiro', 'Okuhara' and 'Wasekogane'.

A split-plot experimental design including three replications was carried out in 1987. Interrow spaces of 50 cm (wide) and 25 cm (narrow), with 5 cm intrarow space (i.e. under density of 40 and 80 plants/m^2, respectively) were assigned to the whole plots and genotypes to the subplots. Sowing was done on May 21. Subplots were 1.5 m wide with rows 1.0 m long. At harvest maturity five plants were sampled from every subplot for biometrical evaluation.

ii. Results

The phenological characteristics of Polish and Japanese genotypes in two levels of interrow space and their analysis of variance were presented in the Table V-1. Differences between two interrow spaces were found in beginning of flowering and harvest maturity. Differences among genotypes were

Table V-1. Phenological characteristics of Polish and Japanese genotypes and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Flowering						Harvest maturity	
	beginning		duration		end			
	50*1	25	50	25	50	25	50	25
Polish								
AR1	49.0	49.3	15.0	14.7	64.0	64.0	121	122
IHA	44.7	45.3	26.0	25.0	70.7	70.3	111	113
S23	45.0	46.3	17.7	16.7	62.7	63.0	111	112
R18	45.3	45.7	24.7	25.0	70.0	70.7	114	113
POL	43.0	44.0	13.0	11.3	56.0	55.3	111	111
PRO	44.3	45.3	11.0	10.3	55.3	55.7	108	110
Mean	45.2	46.0	17.9	17.2	63.1	63.2	113	114
Japanese								
KHO	58.0	58.3	7.0	6.3	65.0	64.7	144	148
TOS	53.0	54.7	9.3	8.3	62.3	63.0	144	150
SHI	60.7	61.3	10.0	9.7	70.7	71.0	142	151
KMI	48.7	60.0	18.7	8.0	67.3	68.0	146	150
OKU	52.3	55.7	11.7	8.7	64.0	64.3	130	148
WKO	53.0	52.7	21.7	22.7	74.7	75.3	132	140
Mean	54.3	57.1	13.1	10.6	67.3	67.7	140	148
Mean*2	49.8	51.6	15.5	13.9	65.2	65.4	126	131
h^2	0.32	0.88	0.36	0.90	0.97	0.96	0.61	0.93

Analysis of variance

Item	d.f.*3		Significance		
Interrow	1	*	ns	ns	**
Genotype	11	**	**	**	**
G x I*4	11	ns	ns	ns	**

Notes:
*1 interrow space [cm]
*2 overall mean
*3 degrees of freedom
*4 genotype x interrow space interaction
**, * significant at 1% and 5% levels, respectively; ns nonsignificant

significant regarding all phenological characteristics examined. The 'genotype x interrow space' interaction was detected only in harvest maturity.

On the average, plants attained earlier maturity in the 50 than 25 cm interrow space. But the effect of interrow space on maturity was not obvious in the Polish genotypes. Except the end of flowering the heritability values of other phenological characteristics were smaller in the 50 than in 25 cm interrow space.

Canopy closure, plant height, branch number and stem diameter responded significantly to the interrow space, and showed interactions between genotypes and interrow spaces (Table V-2). On the average, canopy closure was achieved about two weeks earlier in the narrow interrows than in the wide interrows. The difference in Japanese cultivars between two interrow spaces was greater than in the Polish genotypes. 'Suzuhime' and 'AR1' showed the greatest and the smallest difference in the time of canopy closure between the interrow spaces, respectively (Table V-2).

Plant height was shorter, and branch number and stem diameter were greater in the wide than in the narrow interrow space (Table V-2). The differences in plant height and stem diameter between the interrow spaces were greater for Japanese than Polish genotypes. Considering plant height 'Okuhara' and 'IHAR-NK' responded strongly and 'R18' and 'Progres' responded weakly to interrow space (Table V-2). 'S23' produced relatively many branches in both interrow spaces.

Table V-2. Canopy closure, plant height, branch number, stem diameter and lodging score of Polish and Japanese genotypes and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Canopy closure		Plant height		Branch number		Stem diameter		Lodging score	
	50*1	25	50	25	50	25	50	25	50	25
Polish										
AR1	43.7	34.3	79.0	103.0	1.9	0.9	5.8	4.8	3.6	3.2
IHA	45.7	32.0	85.0	111.4	2.4	0.9	5.0	4.7	3.6	3.5
S23	46.0	32.7	70.6	90.3	3.1	2.3	4.5	4.6	3.6	3.9
R18	45.0	33.0	78.8	88.5	3.0	1.8	4.5	4.7	3.6	2.5
POL	46.3	35.0	67.1	82.0	3.0	1.1	5.3	4.8	3.0	3.2
PRO	46.3	34.0	60.7	74.9	2.7	1.4	4.9	4.5	3.0	2.9
Mean	45.5	33.5	73.5	91.7	2.7	1.4	5.0	4.7	3.4	3.2
Japanese										
KHO	45.3	30.0	107.9	130.5	1.4	0.6	6.4	5.1	3.3	3.9
TOS	45.3	30.3	59.5	85.8	2.7	1.2	6.5	4.7	3.0	4.2
SHI	54.0	34.7	69.7	85.9	1.2	0.3	5.8	4.6	1.6	1.5
KMI	44.0	28.7	101.8	122.7	1.5	0.7	6.2	5.5	3.6	4.2
OKU	43.7	27.7	84.7	120.5	3.1	1.0	6.3	5.3	3.3	4.2
WKO	45.7	33.0	85.6	107.5	1.4	0.0	6.4	5.7	1.6	0.9
Mean	46.3	30.7	84.9	108.8	1.9	0.6	6.3	5.2	2.7	3.2
Mean*2	45.9	32.1	79.2	100.3	2.3	1.0	5.6	4.9	3.1	3.2
h^2	0.04	0.32	0.84	0.91	0.75	0.64	0.44	0.17	0.07	0.48

Analysis of variance

Item	d.f.*3	Significance				
Interrows	1	**	**	**	**	ns
Genotype	11	ns	**	**	**	*
G x I*4	11	*	**	*	**	ns

Notes:
*1 interrow space [cm]
*2 overall mean
*3 degrees of freedom
*4 genotype x interrow space interaction
**, * significant at 1% and 5% levels, respectively; ns nonsignificant

'Wasekogane' failed to produce branches in 25 cm interrow space (Table V-2). Though the difference in the branch number between the interrow spaces was similar in both groups of genotypes, the 'genotype x interrow space' interaction was observed. In the branch number per plant, 'Okuhara' and 'Polan' produced the greatest, 'S23', 'Kitahomare' and 'Kitamishiro' showed the smallest differences between the interrow spaces.

The heritability values were low for canopy closure and lodging score especially in the 50 cm interrow space and for stem diameter in 25 cm interrow space. Plant height and branch number showed relatively higher heritability values in both interrow spaces (Table V-2).

Most of the characteristics of pod distribution in the bottom parts of plant canopy were affected by interrow spaces and showed the 'genotype x interrow space' interactions (Tables V-3 and V-4). Basal pod height was low and numbers of pods in the bottom parts of canopy were absolutely and relatively greater in 50 cm than in 25 cm interrow space. Also in the Polish genotypes basal pods were set lower and in greater numbers in bottom parts of canopy than in Japanese ones. In basal pod height, the Japanese cultivars were more responsive to the interrow space than Polish genotypes. In the Polish genotypes the increase in basal pod height in 25 cm interrow space was negligible (Table V-3). The decrease in pod number in the bottom parts of canopy with the narrow space was greater in the Polish genotypes than in Japanese cultivars

Table V-3. Basal pod height, pod number below 10 cm of plant height and their ratios in Polish and Japanese genotypes, and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Basal pod height		Basal pod ratio		Pod number below 10 cm		Pod number below ratio	
	50*1	25	50	25	50	25	50	25
Polish								
AR1	5.9	12.6	7.4	12.2	4.5	1.3	10.4	5.2
IHA	8.1	13.1	9.5	11.7	0.9	0.5	3.1	2.6
S23	6.8	6.7	9.6	7.4	2.8	1.6	7.8	5.3
R18	8.6	7.2	10.9	8.1	2.7	2.3	7.0	10.0
POL	4.7	5.7	7.0	7.0	3.5	2.1	8.9	11.4
PRO	6.4	4.1	10.5	5.4	3.6	2.4	11.3	13.0
Mean	6.8	8.2	9.2	8.6	3.0	1.7	8.1	7.9
Japanese								
KHO	22.8	29.8	21.1	22.8	0.0	0.2	0.0	1.2
TOS	16.6	22.5	28.1	26.4	0.2	0.3	0.8	2.8
SHI	12.6	17.2	18.1	20.0	0.0	0.2	0.0	0.7
KMI	24.2	36.7	23.8	29.9	0.0	0.2	0.0	1.7
OKU	15.7	38.0	18.5	31.7	0.0	0.2	0.0	1.2
WKO	11.1	15.9	13.0	14.8	0.5	0.2	1.7	1.6
Mean	17.2	26.7	20.4	24.3	0.1	0.2	0.4	1.5
Mean*2	12.0	17.5	14.8	16.5	1.6	1.0	4.3	4.7
h^2	0.94	0.92	0.94	0.86	0.92	0.71	0.87	0.70

Analysis of variance

Item	d.f.*3	Significance			
Interrow	1	**	**	**	ns
Genotype	11	**	**	**	**
G x I*4	11	**	**	**	**

Notes:
*1 interrow space [cm]
*2 overall mean
*3 degrees of freedom
*4 genotype x interrow space interaction
** significant at 1% level; ns nonsignificant

Table V-4. Pod number below 15 cm and below half of plant height and their ratios in Polish and Japanese genotypes, and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Pod number below							
	15 cm		ratio		half*1		ratio	
	50*2	25	50	25	50	25	50	25
Polish								
AR1	9.1	5.1	20.7	21.2	25.9	12.8	59.0	52.9
IHA	3.5	1.7	12.4	9.8	17.2	14.2	60.6	80.5
S23	8.6	4.4	23.8	14.8	23.4	15.5	64.6	52.0
R18	7.4	4.1	19.3	17.8	24.4	11.9	64.0	50.9
POL	8.5	4.2	21.3	22.9	18.0	9.4	45.3	51.5
PRO	8.3	5.1	26.0	27.4	15.6	9.9	48.9	52.8
Mean	7.6	4.1	20.6	19.0	20.8	12.3	57.1	56.8
Japanese								
KHO	0.0	0.2	0.0	1.2	11.8	7.5	48.0	43.6
TOS	0.0	0.2	0.0	1.7	8.0	2.9	31.8	24.7
SHI	1.9	0.6	4.3	2.2	12.8	6.5	29.1	24.2
KMI	0.0	0.2	0.0	1.7	10.8	6.1	41.2	52.2
OKU	0.5	0.2	1.6	1.2	12.9	3.7	45.0	22.7
WKO	1.5	0.9	5.6	6.7	11.4	6.1	41.8	47.9
Mean	0.7	0.4	1.9	2.5	11.3	5.5	39.5	35.9
Mean*3	4.1	2.2	11.3	10.7	16.0	8.9	48.3	46.3
h^2	0.97	0.95	0.95	0.94	0.85	0.79	0.71	0.69

Analysis of variance

Item	d.f.*4	Significance			
Interrow	1	**	ns	**	ns
Genotype	11	**	**	ns	**
G x I*5	11	**	**	**	**

Notes:
*1 of plant height
*2 interrow space [cm]
*3 overall mean
*4 degrees of freedom
*5 genotype x interrow space interaction
** significant at 1% level; ns nonsignificant

(Tables V-3 and V-4). The heritability values of basal pod height and pod number in the bottom parts of canopy were high, oscillating between 0.69 and 0.95 (Tables V-3 and V-4).

In mature plant weight (biomass) and its vegetative components, all sources of variation, except weight per pod, showed interrow effects (Tables V-5 and V-6). Mature plant weight increased substantially in the wide interrow space, compared with narrow interrow space. In spite of differentiated responses of particular genotypes to interrow space, the average reactions of Polish and Japanese genotypes were very similar. Mature plant weight of 'ARl', 'Polan' and 'Wasekogane' increased about twofold when interrow space was doubled from 25 to 50 cm; other genotypes responded to interrow space more moderately. Stem weight in 25 cm interrow space was more than half of that in 50 cm interrow space. Branch weight in 25 cm interrow space was less than half of that in 50 cm interrow space. On the average, stem weight constituted substantially greater fraction of combined stem and branches weight in 25 cm than in 50 cm interrow space, but in 'S23', 'Progres' and 'Kitamishiro' small differences were observed when compared with other genotypes (Table V-5). The heritability values of stem weight were relatively high in both interrow spaces, but the heritability of branch weight was much smaller in 25 cm than in 50 cm interrow space (Table V-5).

The effects of interrow space on threshed pod weight per plant and its components were the same as those on plant

Table V-5. Mature plant weight, stem weight and its ratio, and branch weight of Polish and Japanese genotypes, and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Weight of									
	mature plant		stem		stem ratio		branch		stem and branches	
	50*1	25	50	25	50	25	50	25	50	25
Polish										
ARl	31.1	14.9	5.8	3.4	81.7	94.4	1.3	0.2	7.1	3.6
IHA	21.6	14.5	4.4	3.2	86.3	97.0	0.7	0.1	5.1	3.3
S23	20.0	16.8	2.9	2.8	82.9	84.8	0.6	0.5	3.5	3.3
R18	23.8	16.3	3.8	3.3	82.6	94.3	0.8	0.2	4.6	3.5
POL	25.9	13.1	4.0	2.3	87.0	95.8	0.6	0.1	4.6	2.5
PRO	20.5	13.8	3.5	2.4	89.7	92.3	0.4	0.2	3.9	2.6
Mean	23.8	14.9	4.1	2.9	85.0	93.1	0.7	0.2	4.8	3.1
Japanese										
KHO	23.1	17.3	6.5	4.9	89.0	98.0	0.8	0.1	7.3	5.0
TOS	24.9	15.5	5.2	3.9	75.4	90.7	1.7	0.4	6.9	4.3
SHI	21.3	16.6	4.6	4.7	75.4	97.9	1.5	0.1	6.1	4.8
KMI	21.4	14.7	6.9	5.6	92.0	94.0	0.6	0.4	7.5	5.8
OKU	26.1	14.2	5.7	3.9	81.4	92.9	1.3	0.3	7.0	4.1
WKO	23.9	12.7	7.2	4.6	94.7	100.0	0.4	0.0	7.6	4.6
Mean	23.5	15.2	6.0	4.6	84.7	95.6	1.1	0.2	7.1	4.8
Mean*2	23.6	15.0	5.0	3.8	84.8	94.3	0.9	0.2	5.9	4.0
h^2	0.66	0.21	0.68	0.71	0.77	0.39	0.78	0.37	0.67	0.73

Analysis of variance

Item	d.f.*3	Significance				
Interrow	1	**	**	**	**	**
Genotype	11	*	**	**	**	**
G x I*4	11	**	**	**	**	**

Notes:
*1 interrow space [cm]
*2 overall mean
*3 degrees of freedom
*4 genotype x interrow space interaction
**, * significant at 1% and 5% levels, respectively

Table V-6. Threshed pod weight and weight per pod of Polish and Japanese genotypes, and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Pod weight						Weight per pod	
	plant		stem		branches			
	50*1	25	50	25	50	25	50	25
Polish								
AR1	5.9	2.9	4.4	2.4	1.5	0.5	133	119
IHA	4.8	3.0	3.3	2.6	1.5	0.4	166	172
S23	4.4	3.8	3.3	3.2	1.1	0.6	123	128
R18	5.1	3.2	3.6	2.7	1.5	0.5	134	139
POL	5.4	2.9	4.3	2.6	1.1	0.3	136	159
PRO	4.3	2.7	3.6	2.3	0.7	0.4	135	146
Mean	5.0	3.1	3.8	2.6	1.2	0.5	138	144
Japanese								
KHO	4.4	3.2	3.3	2.8	1.1	0.4	178	184
TOS	5.3	2.1	2.7	1.4	2.6	0.7	211	179
SHI	4.5	2.5	3.4	2.3	1.1	0.2	102	91
KMI	3.7	1.5	2.8	1.4	0.9	0.1	143	129
OKU	5.2	2.2	3.7	1.5	1.5	0.7	179	131
WKO	4.6	2.0	4.3	2.0	0.3	0.0	169	160
Mean	4.6	2.3	3.4	1.9	1.3	0.4	164	146
Mean*2	4.8	2.7	3.6	2.3	1.2	0.4	151	145
h^2	0.26	0.32	0.22	0.42	0.82	0.38	0.54	0.30

Analysis of variance

Item	d.f.*3	Significance			
Interrow	1	**	**	**	ns
Genotype	11	*	*	**	**
G x I*4	11	**	**	**	*

Notes:
*1 interrow space [cm]
*2 overall mean
*3 degrees of freedom
*4 genotype x interrow space interaction
**, * significant at 1% and 5% levels, respectively; ns nonsignificant

weight and its components. The weight reduction in the narrow row space was greater in the Japanese than in Polish genotypes. The greatest reduction was observed in pod weight per plant of 'Toyosuzu', 'Okuhara' and 'AR1' and the smallest in 'S23' (Table V-6). When the interrow space was decreased, the reduction in pod weight on branches was greater (3 times) than on stem (1.6 times). The Japanese cultivars reduced pod weight on branches more strongly than Polish genotypes, 3 and 2.4 times, respectively (Table V-6). 'Wasekogane' responded strongly in pod weight on stem but weakly in pod weight on branches because it branched scarcely in both interrow spaces. The greatest difference in pod weight on branches was observed in 'Toyosuzu' (Table V-6). In threshed weight per pod the Polish genotypes except 'AR1' and the Japanese cultivars except 'Kitahomare' responded inversely to interrow space (Table V-6). The heritability values of pod weight were low, though only of pod weight on branches was high in the 50 cm interrow space (Table V-6).

Seed yield and its components responded to the interrow space except hundred seed weight and ratio of sterile pod number. The 'genotype x interrow space' interaction was observed in all seed yield components except hundred seed weight (Tables V-7 to V-9). Seed yield per plant in the 50 cm interrow space was less than twice of that in 25 cm interrow space. On the average, Polish genotypes produced greater difference between interrow spaces than Japanese cultivars. The greatest difference was found in 'AR1' and 'Polan' which

Table V-7. Seed yield per plant and per day, seed number per plant, hundred seed weight and harvest index of Polish and Japanese genotypes, and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Seed yield /plant		Seed yield /day		Seed number /plant		100 seed weight		Harvest index [%]	
	50*1	25	50	25	50	25	50	25	50	25
Polish										
ARI	17.9	8.3	148	68	98.3	44.7	18.3	18.6	57.6	55.5
IHA	11.5	8.0	104	70	43.2	31.7	26.8	25.1	53.2	54.9
S23	11.9	9.4	107	84	76.1	56.9	15.6	16.6	59.4	56.4
R18	13.9	9.4	122	83	72.8	48.8	19.0	19.2	58.3	57.6
POL	15.7	7.6	141	68	80.9	41.4	19.4	18.3	60.3	57.7
PRO	12.2	8.3	113	75	61.7	41.1	19.9	20.1	59.2	60.4
Mean	13.9	8.5	122	75	72.2	44.1	19.8	19.7	58.0	57.1
Japanese										
KHO	10.8	9.0	75	61	41.2	30.5	26.3	29.6	46.7	52.0
TOS	12.4	9.0	86	60	42.9	31.7	29.0	28.5	49.7	58.1
SHI	10.5	9.3	74	61	90.2	73.2	11.7	12.7	49.5	55.7
KMI	9.7	7.0	67	47	44.3	29.0	22.1	24.2	45.6	47.6
OKU	13.8	7.8	106	53	46.5	28.3	29.8	27.6	52.7	54.8
WKO	11.6	6.1	88	43	60.9	30.9	19.1	19.6	48.7	47.9
Mean	11.5	8.0	83	54	54.3	37.3	23.0	23.7	48.8	52.7
Mean*2	12.7	8.3	103	64	63.3	40.7	21.4	21.7	53.4	54.9
h^2	0.61	0.29	0.87	0.52	0.80	0.89	0.77	0.74	0.53	0.54

Analysis of variance

Item	d.f.*3	Significance				
Interrow	1	**	**	**	ns	*
Genotype	11	**	**	**	**	**
G x I*4	11	**	**	**	ns	*

Notes:
*1 interrow space [cm]
*2 overall mean
*3 degrees of freedom
*4 genotype x interrow space interaction
**, * significant at 1% and 5% levels, respectively
ns nonsignificant

Table V-8. Pod number per plant, seed number per pod, and sterile pod number per plant and its ratio in Polish and Japanese genotypes, and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Number of pods/plant		Number of seeds/pod		Sterile pod number per plant		Sterile pod number ratio	
	50*1	25	50	25	50	25	50	25
Polish								
AR1	47.6	26.8	2.2	1.8	3.5	2.7	7.4	10.1
IHA	31.4	19.7	1.5	1.8	2.7	2.0	8.6	10.2
S23	40.7	33.2	2.1	1.9	4.3	3.4	10.6	10.2
R18	41.9	25.2	1.9	2.1	3.7	1.8	8.8	7.1
POL	43.7	20.7	2.0	2.3	3.9	2.4	8.9	11.6
PRO	34.2	20.0	2.0	2.2	2.5	1.3	7.3	6.5
Mean	39.9	24.3	2.0	2.0	3.4	2.3	8.6	9.3
Japanese								
KHO	29.7	18.6	1.7	2.7	5.0	1.5	16.8	8.1
TOS	28.3	13.1	1.7	2.7	3.1	1.3	11.0	9.9
SHI	45.7	28.4	2.1	2.5	1.9	0.9	4.2	3.2
KMI	31.7	15.3	1.7	1.7	5.5	3.5	17.4	22.9
OKU	31.3	17.6	1.6	2.5	2.3	1.1	7.3	6.3
WKO	27.9	12.8	2.2	2.2	0.7	0.1	2.5	0.8
Mean	32.4	17.6	1.8	2.4	3.1	1.4	9.9	8.5
Mean*2	36.2	21.0	1.9	2.2	3.3	1.8	9.2	8.9
h^2	0.81	0.91	0.43	0.49	0.81	0.71	0.84	0.75

Analysis of variance

Item	d.f.*3	Significance			
Interrow	1	**	**	**	ns
Genotype	11	**	*	**	**
G x I*4	12	**	**	**	**

Notes:
*1 interrow space [cm]
*2 overall mean
*3 degrees of freedom
*4 genotype x interrow space interaction
**, * significant at 1% and 5% levels, respectively; ns nonsignificant

Table V-9. Pod number on stem and branches, and their ratios in Polish and Japanese genotypes, and heritability (h^2) in 50 and 25 cm interrow space, 1987

Genotype	Pod number on							
	stem		ratio		branches		ratio	
	50*1	25	50	25	50	25	50	25
Polish								
AR1	33.1	21.3	75.0	88.2	11.0	2.9	25.0	11.8
IHA	20.7	15.9	72.1	89.8	8.0	1.8	27.9	10.2
S23	25.0	23.6	68.6	79.3	11.4	6.2	31.4	20.7
R18	26.9	19.2	70.3	82.1	11.3	4.2	29.7	17.9
POL	29.7	16.6	74.7	90.5	10.1	1.7	25.3	9.5
PRO	24.6	16.7	77.5	89.2	7.1	2.1	22.5	10.8
Mean	26.7	18.9	73.0	86.5	9.8	3.2	27.0	13.5
Japanese								
KHO	18.2	15.1	73.6	88.0	6.5	2.1	26.4	12.0
TOS	14.1	8.5	56.2	71.7	11.0	3.3	43.8	28.3
SHI	33.2	25.4	76.1	92.5	10.6	2.1	23.9	7.5
KMI	19.1	10.5	73.2	88.9	7.0	1.3	26.8	11.1
OKU	18.5	9.3	64.0	56.0	10.4	7.2	36.0	44.0
WKO	26.3	12.7	96.7	100.0	0.9	0.0	3.3	0.0
Mean	21.6	13.6	73.3	82.9	7.7	2.7	26.7	17.2
Mean*2	24.1	16.2	73.2	84.7	8.8	2.9	26.8	15.3
h^2	0.79	0.93	0.86	0.77	0.77	0.74	0.86	0.77

Analysis of variance

Item	d.f.*3	Significance			
Interrow	1	*	**	**	**
Genotype	11	**	**	**	**
G x I*4	11	**	**	**	**

Notes:
*1 interrow space [cm]
*2 overall mean
*3 degrees of freedom
*4 genotype x interrow space interaction
**, * significant at 1% and 5% levels, respectively

produced higher seed yield per unit of area in wide than narrow interrow space. 'S23', 'R18' and 'Suzuhime' yielded best in the 25 cm interrow space and also per unit of area (Table V-7).

In daily seed yield efficiency (seed yield per day) the genotypes varied highly regarding the response to interrow space. Considering vegetation period, the Polish genotypes produced seed more efficiently than Japanese cultivars. In the 50 cm interrow space the most efficient were 'AR1' and 'Polan'. However, 'S23' and 'R18' in the 25 cm interrow space were most promising, because of high daily seed efficiency. Seed number per plant followed the variation of seed yield per plant (Table V-7). When interrow space was reduced, the Japanese cultivars except 'Wasekogane' increased and Polish genotypes except 'IHAR-NK' and 'Progres' decreased their harvest indices (Table V-7). The heritability values of seed yield and its daily efficiency were greater in the wide than in narrow interrow space. In seed number per plant, hundred seed weight and harvest index, differences in heritability values between interrow spaces were small (Table V-7).

Pod number per plant responded to the interrow space in a similar way to the seed yield and seed number per plant. On the average, pod numbers in the 25 cm interrow space decreased to two thirds on stem and one third on branches as compared to 50 cm interrow space (Table V-9). In the 25 cm interrow space, 'Wasekogane' did not produce branches and all its pod production came from the stem. The ratio of pod

number on stem increased strongly with interrow space reduced (Table V-9). 'Wasekogane', 'AR1' and 'Polan' produced the greatest and 'S23' and 'Kitahomare' produced the smallest difference in pod number on stem between the interrow spaces. Regarding pod number on branches most of the genotypes responded strongly and only 'Okuhara' and 'S23' responded weakly to the interrow space (Table V-9). The heritability values of pod number per plant and its components were high and those of seed number per pod were moderate (Tables V-8 and V-9).

3. Response to intrarow space (interrow space constant)

i. Materials and methods

Four Polish genotypes: 'AR1', 'S23', 'Polan' and 'Progres' as super-early, and two Japanese cultivars: 'Suzu-hime' and 'Wasekogane' as early genotypes were used.

A split-plot experimental design with three replications was carried out in 1988. One replication was damaged by herbicide drift and excluded from statistical calculations. Intrarow spaces were assigned to the main plots and genotypes were assigned to the subplots. Sowing was done on May 27. Subplots consisted of three rows 50 cm apart and 1.5 m long. Four seeds per hill were planted and thinned to two plants after emergence. Intrarow space (between hills) of 20, 10, 5 and 3.3 cm produced the densities of 20, 40, 80 and 120 plants/m^2 (2 plants/hill x number of hills/m of row x 2 rows/m makes planting density viz. the number of plants/m^2). For quantitative recordings ten fully matured plants were sampled from each subplot. Analysis of variance with regression on the intrarow space of 20, 10, 5 and 3.3 cm corresponding to plant density of 20, 40, 80 and 120 plants/m^2 was conducted.

ii. Results

Intrarow spacing affected most of the characteristics except phenological ones.

In plant height the 'cultivar x intrarow space' interaction and in branch number and stem diameter the pooled deviations were detected (Table V-10). In plant height the response of particular genotypes to intrarow space was highly specific. The Japanese cultivars tended to reduce and Polish genotypes to increase plant height when intrarow space was decreased (Table V-10). However, on the average, plant height increased when intrarow space was reduced (Fig. V-1), as shown in the interrow space density in the previous section.

Stem node number (Table V-10), branch number (Fig. V-2) and also stem diameter (Fig. V-3) decreased with high density of intrarow space and 'genotype x intrarow space' interactions were not observed (Table V-10).

In the characteristics of mature plant weight (biomass) (Table V-10), the linear regression and its 'cultivar x intrarow space' interaction were detected. The pooled deviations were found in mature plant weight and stem weight. Mature plant weight and also its vegetative parts decreased with intrarow spaces reducing (Fig. V-4). In mature plant and stem weight, the Polish genotypes reacted moderately to intrarow space. 'Suzuhime' responded strongly to the intrarow space in stem and in branch weight (Table V-10).

Harvest index slightly decreased in response to the

Table V-10. Linear regression coefficients (x10) on intrarow space (20, 10, 5 and 3.3 cm) and analysis of variance of morphological characteristics, lodging score, mature plant weight and its components, and harvest index of Polish and Japanese genotypes, 1988

Genotype	Plant height	Stem node number	Branch number	Stem diameter	Lodging score	Weight of mature plant	Weight of branches	Weight of stem	Harvest index
WKO	1.6	2.8	1.8	1.5	0.0	11.0	1.0	0.6	2.5
SHI	0.7	2.3	2.5	1.4	-0.1	14.2	1.1	1.1	3.6
AR1	-3.9	2.1	2.1	1.0	-0.6	10.3	0.4	0.8	2.6
S23	-1.3	1.6	1.9	0.9	-0.3	7.8	0.3	0.5	3.9
POL	-7.2	2.1	2.1	0.8	-0.2	8.5	0.3	0.5	3.2
PRO	-5.8	1.9	1.6	0.9	-0.2	8.2	0.3	0.5	0.9
LSD 5%	6.8	ns	ns	ns	ns	3.9	0.8	0.2	ns

Analysis of variance

Item	d.f.*	Significance								
a	1	**	**	**	**	ns	**	**	**	**
b	5	**	**	**	**	*	**	**	**	*
c	5	*	ns	ns	ns	ns	**	**	**	ns
d	12	ns	ns	**	**	ns	*	**	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
f	23	12.4	4.6	1.7	8.7	2.4	2.3	4.7	1.8	15.0

Notes:
a linear regression (intrarow space effect)
b genotype effect
c genotype x intrarow space interaction
d pooled deviations
e replications
f error (mean square)
* degrees of freedom
*, ** significant at the 5% and 1% levels, respectively
ns nonsignificant

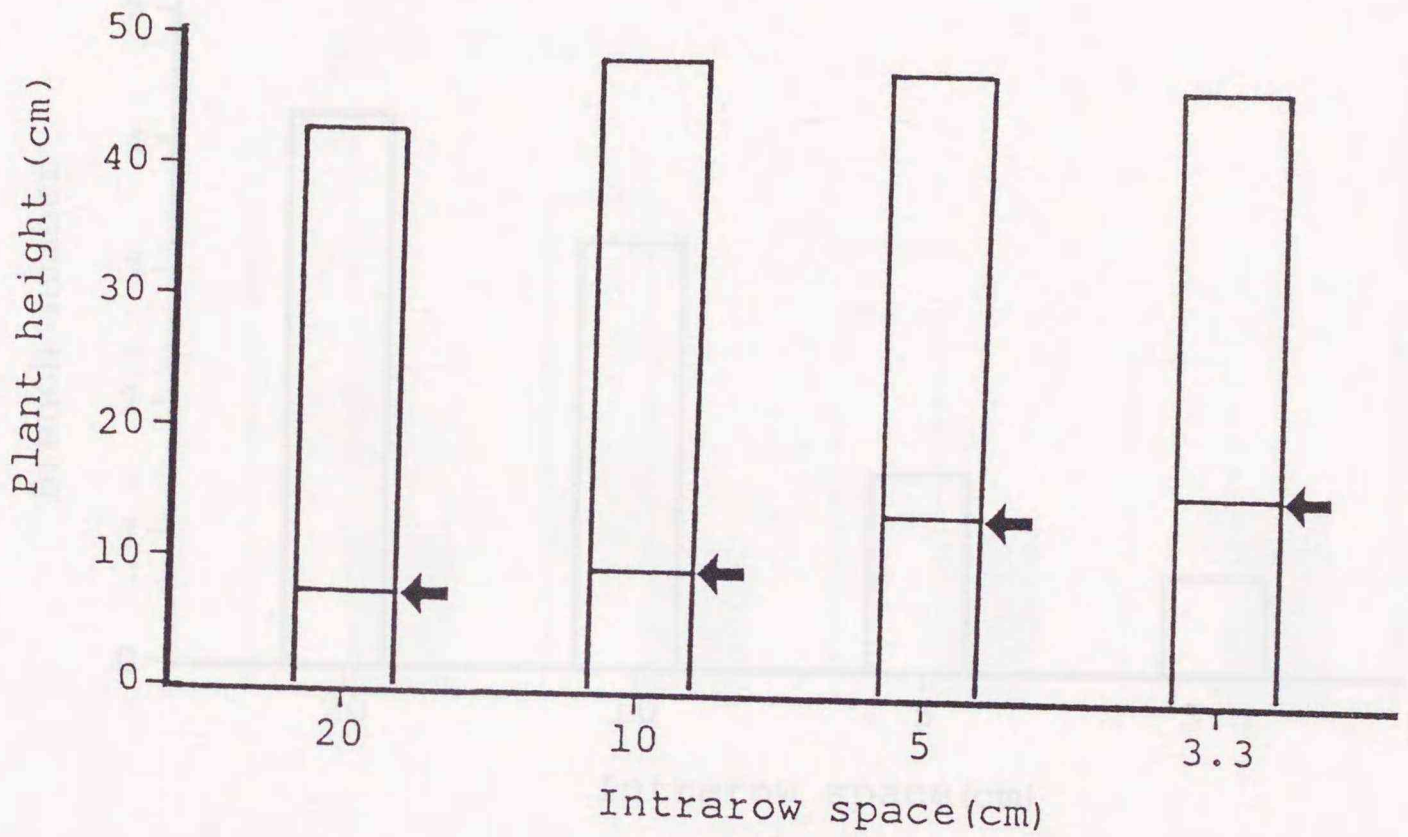


Fig. V-1. Plant height and basal pod height in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

← Basal pod height

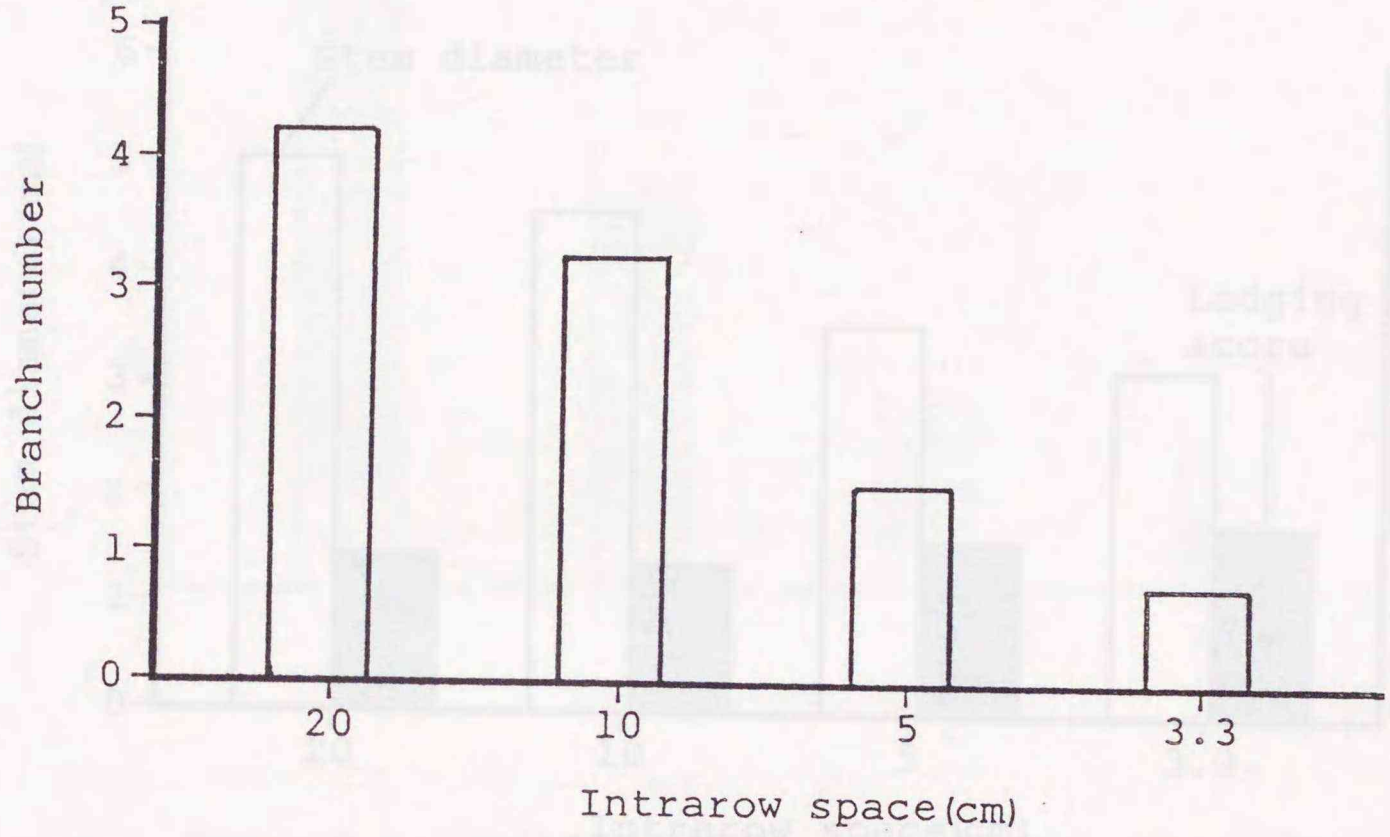


Fig. V-2. Branch number in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

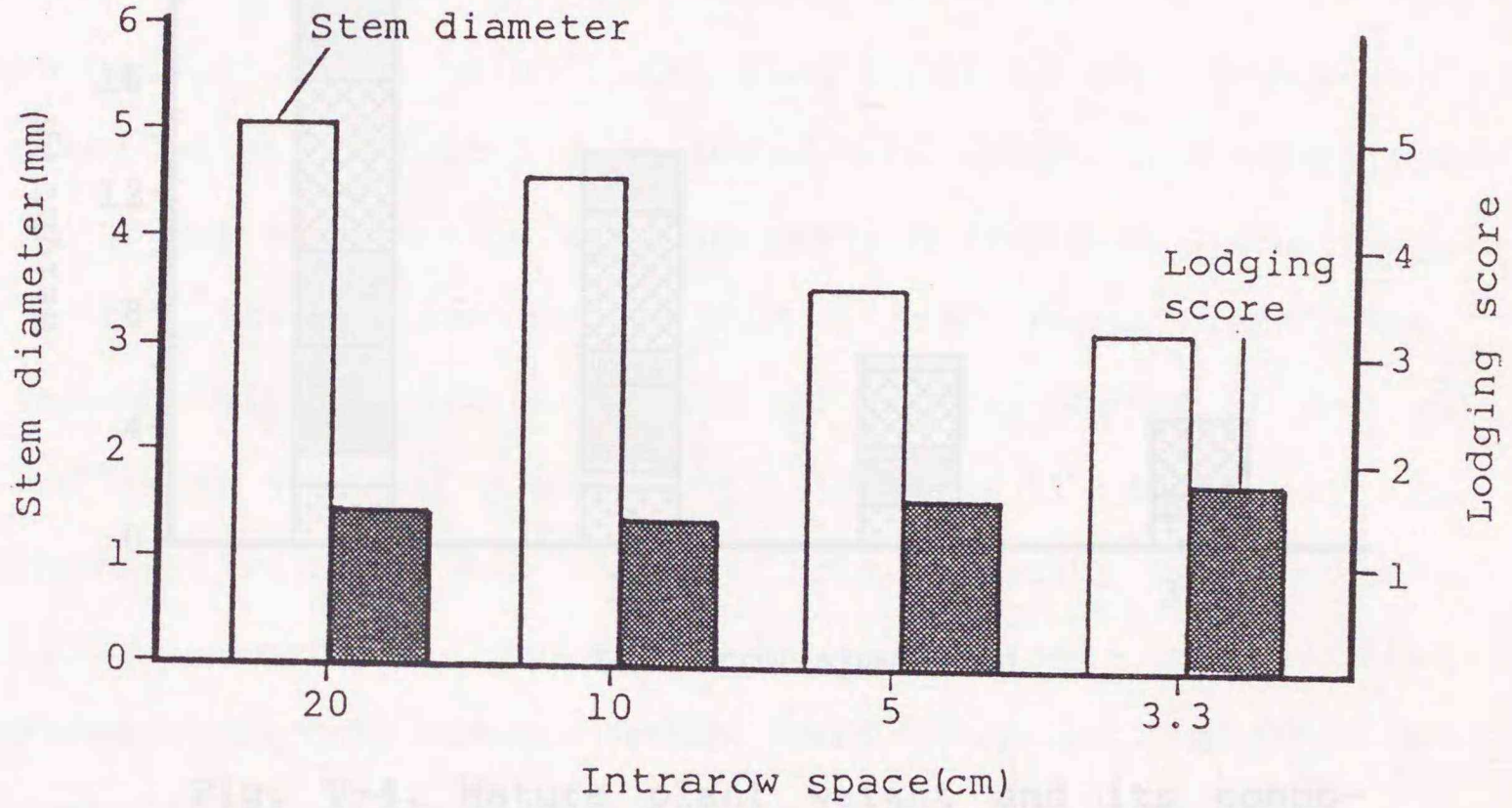


Fig. V-3. Stem diameter and lodging score in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

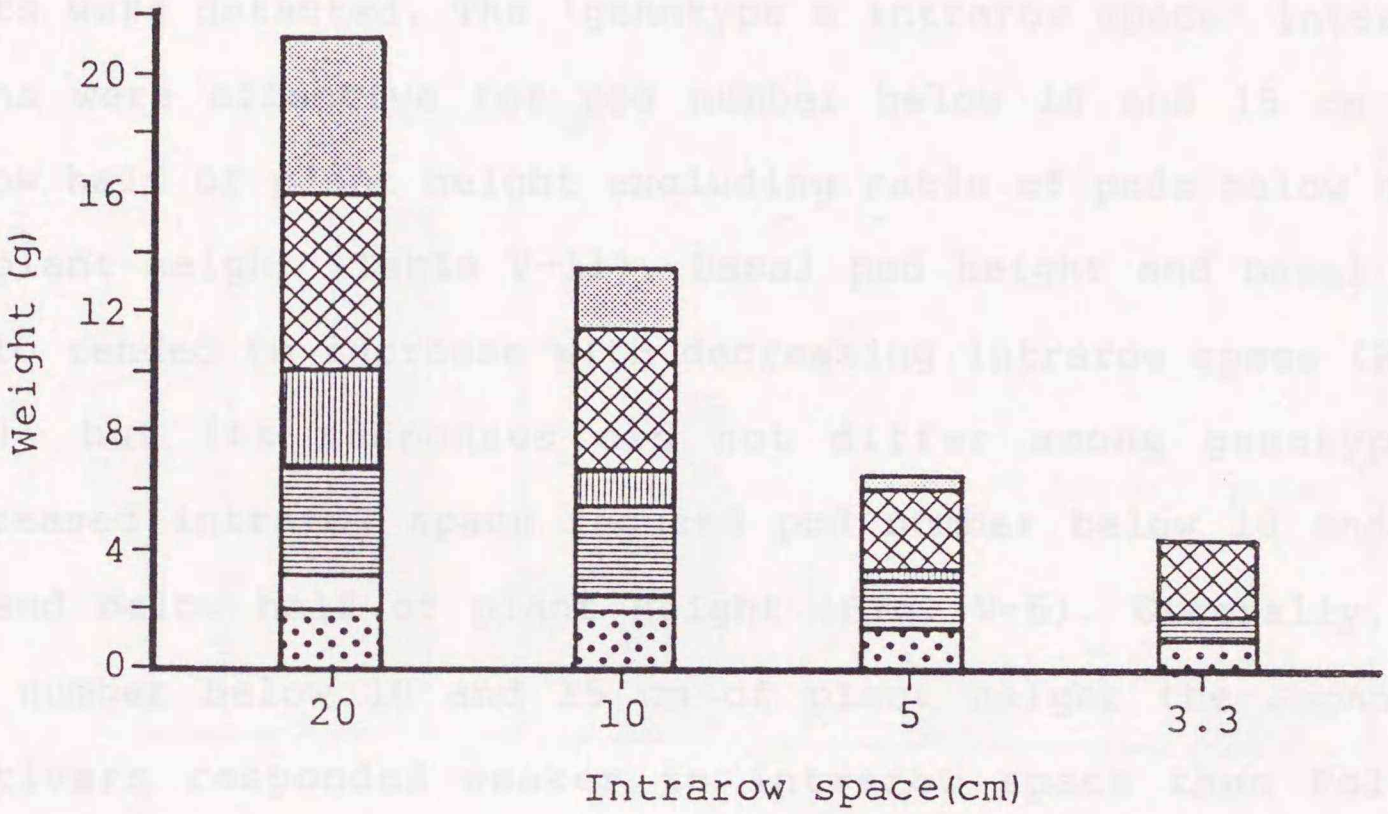


Fig. V-4. Mature plant weight and its components in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

decreasing of intrarow space (Fig. V-5), but its 'genotype x intrarow space' interaction was not effective.

In the characteristics of pod distribution on the bottom parts of plant canopy, the intrarow space and genotype effects were detected. The 'genotype x intrarow space' interactions were effective for pod number below 10 and 15 cm and below half of plant height excluding ratio of pods below half of plant height (Table V-11). Basal pod height and basal pod ratio tended to increase with decreasing intrarow space (Fig. V-1), but its responses did not differ among genotypes. Decreased intrarow space reduced pod number below 10 and 15 cm and below half of plant height (Fig. V-6). Generally, in pod number below 10 and 15 cm of plant height the Japanese cultivars responded weaker to intrarow space than Polish genotypes. In pod number below half of plant height, the Japanese cultivars responded strongly and the Polish genotypes did more diversely (Table V-11).

Threshed pod weight per plant, on stem, on branches, and sterile pod weight (Fig. V-4) and weight per pod (Fig. V-7) reduced their values when intrarow space was decreased (Table V-12). The 'genotype x intrarow space' interaction was observed in pod weight per plant and weight per pod on branches. Pod weight on stem showed effective pooled deviations from linearity, indicating the curvilinear response (Table V-12).

'Suzuhime' reacted strongly and some of Polish genotypes did not in pod weight per plant and its fractions (Table V-

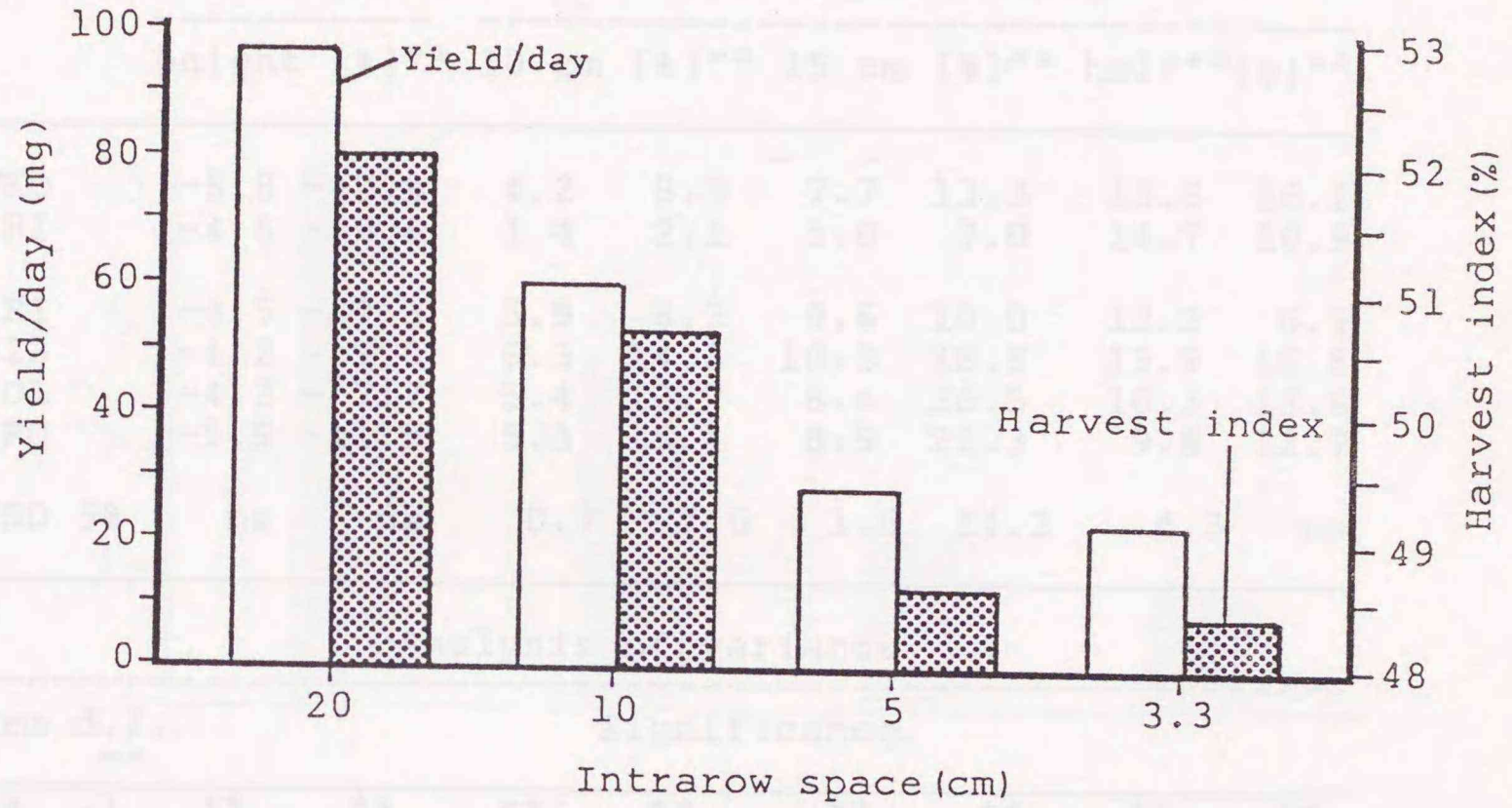


Fig. V-5. Daily seed yield efficiency and harvest index in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

Table V-11. Linear regression coefficients (x10) on intrarow space (20, 10, 5 and 3.3 cm) and analysis of variance of characteristics of pod distribution on bottom parts of stature of Polish and Japanese genotypes, 1988

Genotype	Basal pod		Pod number below					
	height [%]*1		10 cm [%]*2		15 cm [%]*2		half*3 [%]*2	
WKO	-5.8	-12.9	4.2	9.3	7.7	13.3	13.8	16.2
SHI	-4.8	- 9.6	1.4	2.1	5.0	7.0	14.7	10.9
AR1	-4.5	- 9.3	5.9	8.3	9.6	10.0	12.2	6.5
S23	-4.2	- 9.0	6.3	14.3	10.8	18.8	13.9	16.8
POL	-4.3	- 7.7	5.4	13.7	8.4	16.5	10.3	13.6
PRO	-5.9	-11.5	5.3	15.4	8.9	21.3	9.8	12.7
LSD 5%	ns	ns	0.7	7.6	1.6	14.2	4.3	ns

Analysis of variance

Item	d.f.*4	Significance							
a	1	**	**	**	**	**	**	**	**
b	5	**	**	**	**	**	**	*	**
c	5	ns	ns	**	**	**	*	*	ns
d	12	**	**	ns	ns	ns	*	ns	**
e	1	ns	ns	ns	ns	ns	ns	ns	ns
f	23	1.7	11.6	6.8	11.2	9.9	26.9	4.5	32.5

Notes:
*1 ratio to plant height
*2 ratio to total pod number per plant
*3 of plant height
*4 degrees of freedom
a linear regression (intrarow space effect)
b genotype effect
c genotype x intrarow space interaction
d pooled deviations
e replications
f error (mean square)
*, ** significant at the 5% and 1% levels, respectively
ns nonsignificant

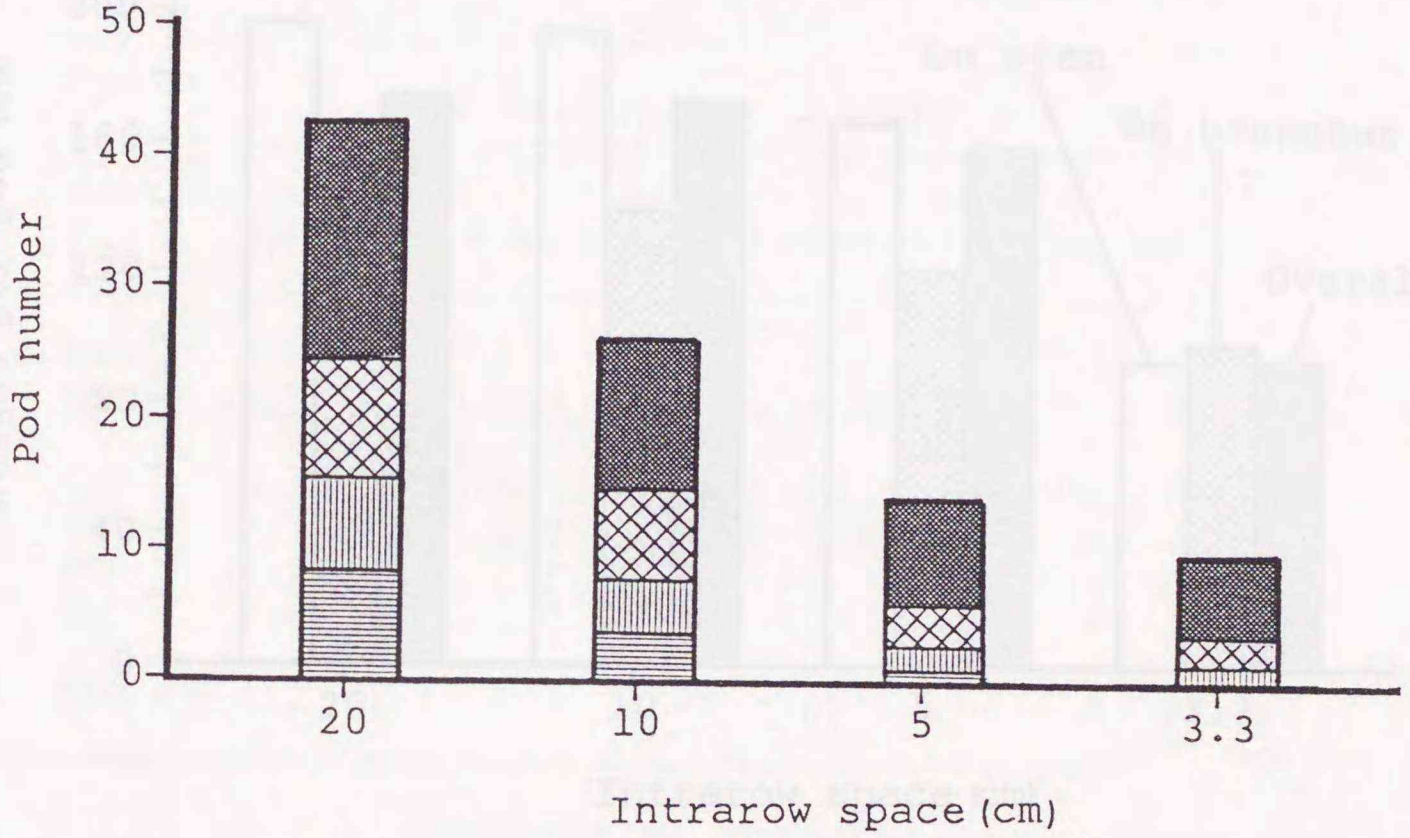


Fig. V-6. Pod distribution along canopy height in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

Upper half of plant height
15 cm - half of plant height
10-15 cm
<10 cm

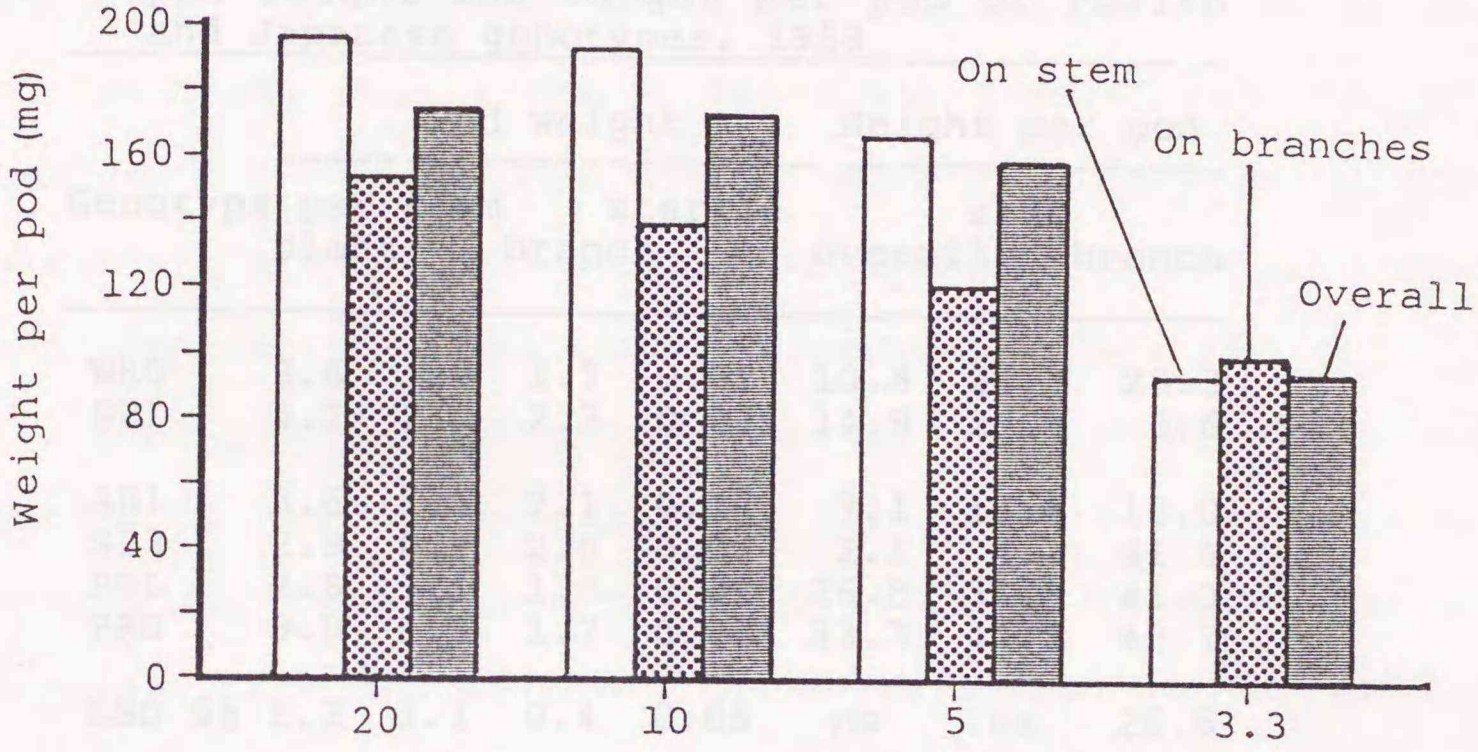


Fig. V-7. Weight per pod on stem, on branches and overall in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

Table V-12. Linear regression coefficients (x10) on intrarow space (20, 10, 5 and 3.3 cm) and analysis of variance of threshed pod weight and weight per pod of Polish and Japanese genotypes, 1988

Genotype	Pod weight			Weight per pod			
	per plant	stem	sterile branch		overall	stem	branch
WKO	3.6	1.9	1.7	0.02	10.8	24.7	20.3
SHI	4.2	2.0	2.3	0.01	14.9	28.4	9.6
AR1	3.6	1.5	2.1	0.17	7.1	15.6	10.0
S23	2.9	0.9	2.0	0.04	2.1	4.3	41.4
POL	2.8	1.1	1.7	0.05	26.8	34.9	41.0
PRO	3.0	1.3	1.7	0.01	33.3	44.3	42.7
LSD 5%	1.2	1.1	0.4	0.08	ns	ns	26.6

Analysis of variance

Item	d.f.*	Significance						
a	1	**	**	**	**	**	**	**
b	5	**	**	ns	**	**	**	ns
c	5	*	*	*	**	ns	ns	*
d	12	ns	*	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns
f	23	3.6	1.9	0.9	2.0	37.8	47.8	42.0

Notes:
* degrees of freedom
a linear regression (intrarow space effect)
b genotype effect
c genotype x intrarow space interaction
d pooled deviations
e replications
f error (mean square)
*, ** significant at the 5% and 1% levels, respectively; ns nonsignificant

12). The reaction of weight per pod on branches to intrarow space was observed in the Polish genotypes except 'AR1'. The response of sterile pod weight was small (Table V-12).

Pod number per plant (Fig. V-8) and seed number per pod (Fig. V-9) decreased with reduction in the intrarow space. 'Suzuhime' strongly decreased its pod number (both on stem and branches) when intrarow space was reduced but its total sterile pod number was highly stable throughout applied intrarow spaces. 'AR1' sharply reduced its number of sterile pods when intrarow space was decreased (Table V-13).

Seed yield on stem and branches (Fig. V-4), daily seed yield efficiency (seed yield per day) (Fig. V-5), seed number on stem and branches (Fig. V-10)) tended to decrease when intrarow space was reduced. 'Suzuhime' responded to intrarow space stronger than some of Polish genotypes in seed yield per plant and its components. Super-early genotypes 'S23', 'Polan' and 'Progres' showed the weakest reaction to intrarow space (Table V-14).

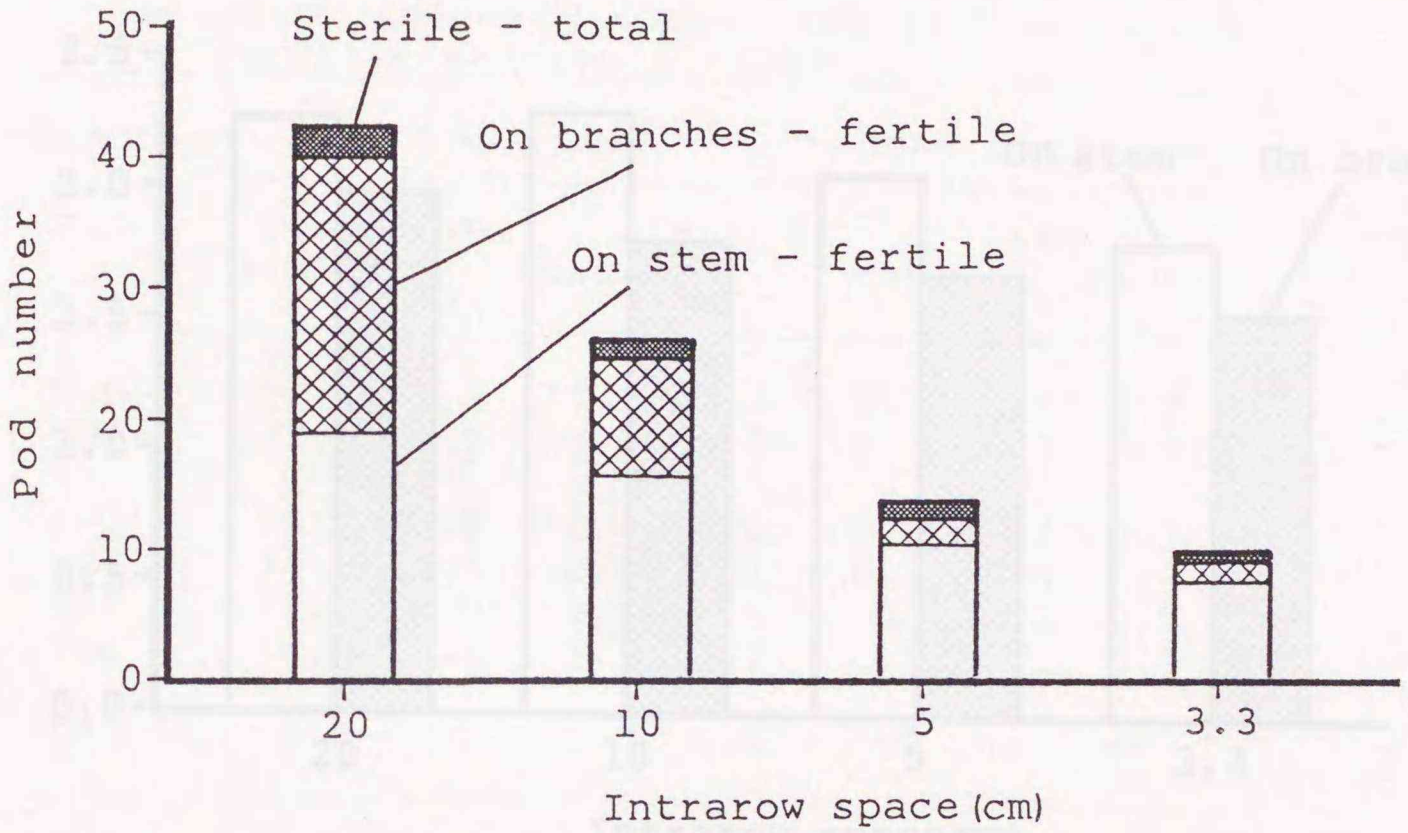


Fig. V-8. Pod number per plant and its components in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

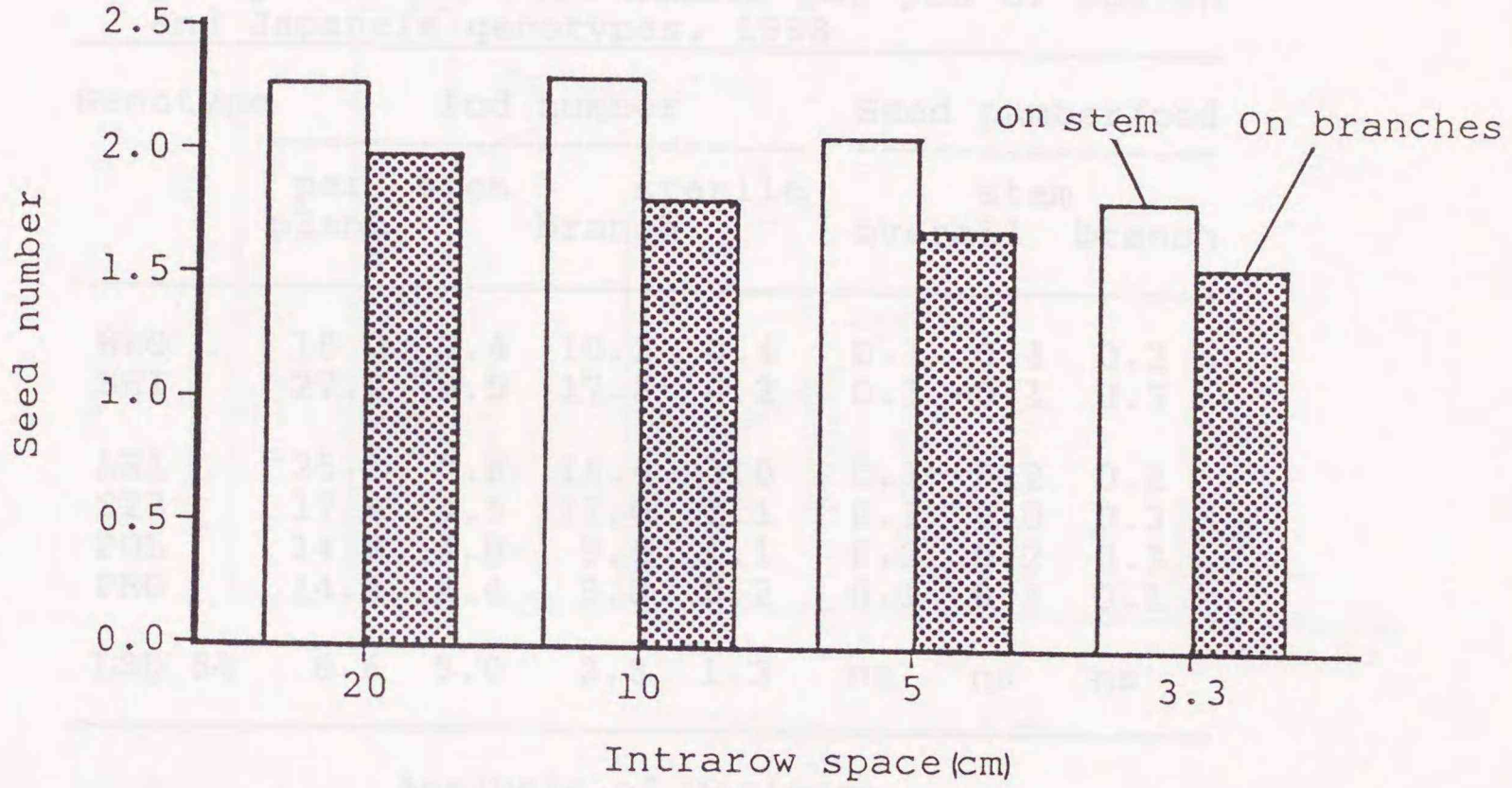


Fig. V-9. Seed number per pod on stem and branches in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

Table V-13. Linear regression coefficients (x10) on intrarow space (20, 10, 5 and 3.3 cm) and analysis of variance of pod number per plant and seed number per pod of Polish and Japanese genotypes, 1988

Genotype	Pod number				Seed number/pod		
	per plant	stem	branch	sterile branch	stem overall	branch	
WKO	18.0	7.4	10.2	0.4	0.1	0.1	0.2
SHI	27.0	9.5	17.3	0.2	0.1	-0.1	0.5
AR1	25.2	7.8	14.4	3.0	0.1	0.2	0.2
S23	17.6	4.5	12.0	1.1	0.1	0.0	0.3
POL	14.9	4.0	9.8	1.1	0.2	0.2	0.3
PRO	14.4	4.4	9.8	0.2	0.1	0.1	0.1
LSD 5%	6.6	5.0	2.3	1.3	ns	ns	ns

Analysis of variance

Item	d.f.#	Significant						
a	1	**	**	**	**	**	ns	**
b	5	**	**	**	**	**	*	**
c	5	**	**	**	**	ns	ns	ns
d	12	ns	**	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns
f	23	9.5	2.8	2.5	3.3	1.9	5.5	8.0

Notes:
degrees of freedom
a linear regression (intrarow space effect)
b genotype effect
c genotype x intrarow space interaction
d pooled deviations
e replications
f error (mean square)
*, ** significant at the 5% and 1% levels, respectively; ns nonsignificant

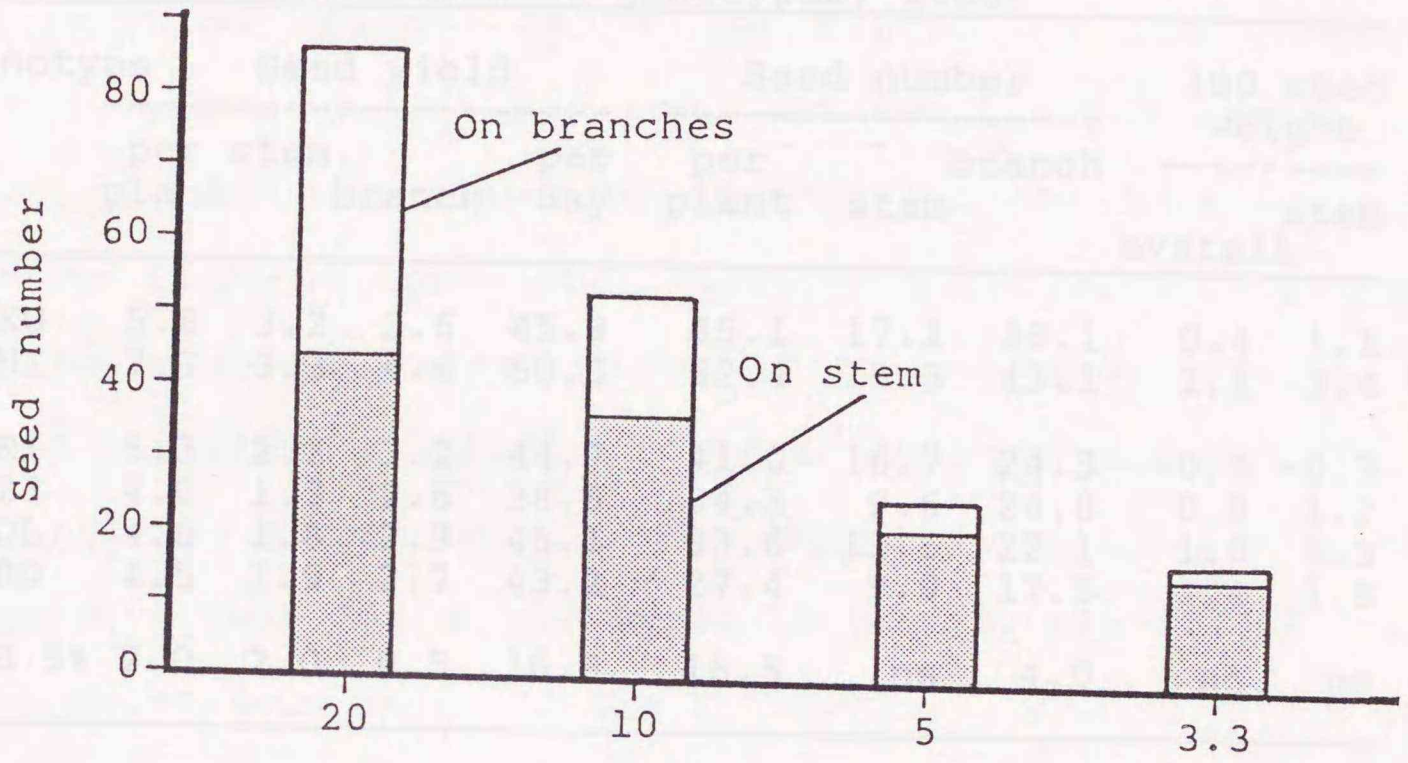


Fig. V-10 Seed number per plant, on stem and branches in intrarow space of 20, 10, 5 and 3.3 cm over Polish and Japanese genotypes in 1988

Table V-14. Linear regression coefficients (x10) on intrarow space (20, 10, 5 and 3.3 cm) and analysis of variance of seed yield per plant and its components of Polish and Japanese genotypes, 1988

Genotype	Seed yield			Seed number			100 seed weight	
	per plant	stem branch	per day	per plant	branch stem		stem	overall
WKO	5.8	3.2	2.6	45.9	35.1	17.1	18.1	0.4	1.1
SHI	7.7	3.3	4.4	60.3	62.4	19.3	43.1	1.1	3.4
AR1	5.3	2.2	3.2	44.7	41.0	16.7	24.3	-0.4	-0.3
S23	4.0	1.3	2.6	38.6	34.3	9.6	24.8	0.9	1.2
POL	4.8	1.8	2.9	45.1	33.6	11.5	22.1	1.0	1.3
PRO	4.5	1.9	2.7	43.2	27.4	9.9	17.5	1.4	1.8
LSD 5%	2.0	2.0	0.5	16.9	16.5	ns	4.0	ns	ns

Analysis of variance

Item	d.f.#	Significance							
a	1	**	**	**	**	**	**	**	*	**
b	5	**	**	**	*	**	**	**	**	**
c	5	**	**	**	*	**	ns	**	ns	ns
d	12	ns	**	ns	ns	*	*	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
f	23	7.2	2.8	2.3	63.3	42.5	34.7	15.7	2.4	4.2

Notes:
degrees of freedom
a linear regression (intrarow space effect)
b genotype effect
c genotype x intrarow space interaction
d pooled deviations
e replications
f error (mean square)
*, ** significant at the 5% and 1% levels, respectively
ns nonsignificant

4. Discussion

The present experiments indicated in many of characteristics examined that the super-early and early genotypes responded differently to plant density altered by interrow and intrarow spaces. As it was evident in plant height, branch weight, weight per pod, and sterile pod number, the Japanese cultivars responded stronger to the interrow space than to intrarow space when compared with Polish genotypes. In stem weight and also combined stem and branch weight, pod weight per plant (including its fractions on stem and branches), and pod number on stem the Japanese cultivars were more responsive than Polish genotypes in density altered by interrow and intrarow space (Table V-15).

The results concerning harvest maturity confirmed the phenological data delivered by Green et al. (1977) who found earlier harvest maturity in the low plant density with wide interrow space than in the high plant density with narrow interrow space. It was found in the phenological characteristics that early maturing Japanese genotypes were more sensitive to the interrow space density than the super-early maturing Polish genotypes. On the other hand, the impact of intrarow space on phenological characteristics was not detected. This confirmed earlier observations of Wilcox (1974) - equidistant spacing; Lueschen and Hicks (1977) - intrarow space. Apparently the difference in intrarow spaces (within constant interrows) did not stimulate substantial changes in

Table V-15. Sensitivity of Polish and Japanese genotypes to plant density altered by interrow and intrarow space

Characteristic	Interrow space			Intrarow space		
	Polish[1] versus Japanese	Genotype[&] strong	Genotype[&] weak	Polish versus Japanese	Genotype strong	Genotype weak
Harvest maturity	P<J	OKU,SHI	POL,AR1	---[¥]	---	---
Canopy closure	P<J	SHI	AR1	*	*	*
Plant height	P<J	OKU,KHO	R18,PRO	P>J	POL,PRO	SHI
Branch number	P=J	OKU	S23	---	---	---
Stem diameter	P<J	TOS	S23,R18	---	---	---
Lodging score	---	---	---	---	---	---
Basal pod height	P<J	OKU	S23,Pol	---	---	---
ratio	P<J	OKU	POL,SHI	---	---	---
Pods <10 cm	P>J	AR1	TOS	P>J	S23,AR1	SHI,WKO
ratio	P=J	AR1	WKO	P>J	PRO,S23	SHI
Pods <15 cm	P>J	POL,S23	KHO,TOS	P>J	S23,AR1	SHI,WKO
ratio	P=J	S23	OKU	P=J	PRO	SHI
Pods <half ht	P=J	AR1	IHA	P=J	SHI	PRO
ratio	P=J	OKU	PRO	---	---	---
Biomass - total	P=J	AR1,POL	S23,SHI	P<J	SHI,WKO	S23
- stem	P=J	WKO,AR1	S23,SHI	P<J	SHI,WKO	S23,POL
ratio	P=J	SHI	S23,KMI	*	*	*
- branch	P=J	SHI,TOS	S23,PRO	P=J	SHI,AR1	S23,POL
stem+branch	P=J	AR1,WKO	S23	*	*	*
Pod weight/plant	P=J	TOS,AR1	S23	P=J	SHI	POL
stem	P=J	WKO,OKU	S23,KHO	P=J	SHI,WKO	S23
branch	P=J	TOS	PRO,WKO	P=J	SHI	POL,PRO
Weight/pod	P<J	OKU,TOS	S23,R18	P>J[$]	PRO,S23	SHI
Seed yield/plant	P>J	AR1,POL	SHI,KHO	P<J	SHI,WKO	S23,PRO
/day	P>J	AR1,POL	SHI,KHO	P<J	SHI,WKO	S23,PRO
Seed no./plant	P>J	AR1,POL	KHO,TOS	P=J	SHI	PRO
100 seed weight	---	---	---	---	---	---
Harvest index	P<J	TOS,SHI	R18	---	---	---
Pod number/plant	P=J	POL,AR1	S23,KHO	P=J	SHI,AR1	PRO,POL
stem	P=J	WKO	S23	P=J	SHI	POL,PRO
ratio	P>J	IHA,SHI	WKO	*	*	*
branches	P=J	SHI,POL	WKO	P=J	SHI	POL,PRO
ratio	P>J	IHA,SHI	WKO	*	*	*
Sterile pod no.	P=J	KHO	WKO,IHA	P=J	AR1	SHI,PRO
ratio	P=J	KHO,KMI	S23	*	*	*
Seed number/pod	P<J	KHO,TOS	KMI,WKO	---	---	---

[1] comparison in response between Polish and Japanese genotypes
[&] comparison in response among the genotypes examined
[¥] no interaction of 'genotype x interrow or intrarow space'
[*] no observation data
[$] branch pod weight

developmental processes of genotypes examined. It seems that the interaction of genotypes with interrow space may be affected by other (e.g. growth limiting) factors accidentally involved in experiments. Inadequate field conditions of intrarow space experiment could reduce impact on differentiation of phenological characteristics either (Doss and Thurlow, 1974; Taylor, 1980; Alessi and Power, 1982; Reicosky et al., 1982; Cooper and Jeffers, 1984). Another example was lack of canopy closure in 1988 due to poorer field conditions than in 1987. That illustrated impact of environment on soybean growth potential. An early canopy closure of Japanese cultivars under the narrow interrow conditions revealed their higher potential in expanding plant stature and filling available space than super-early, short stature Polish genotypes. Genotypes which closed the canopy rapidly may be able to intercept earlier the available photosynthetically active radiation. Moreover, they could shade the soil early and that might prevent weed emerging, halt excessive evaporation, and keep the soil temperature and microclimate among plants more stable. Yet, that advantage was not enough to produce optimal yields by Japanese genotypes. Early canopy closure of Japanese cultivars indicated that they should be cultivated in low density plantings. The opposite can be stated about Polish genotypes, which are habitually grown in the northern limit of soybean cultivation zone where optimum yielding requires dense populations and narrow interrow space.

In plant height, differentiated response of particular

genotypes to interrow and intrarow space proved genetic complexity of the characteristic and its dependence on spatial conditions. Interaction between genotypes and density treatments (interrow and intrarow space) indicated specific response of genotypes to applied interrow and intrarow spaces. Apparently depending on density stress, e.g. interrow and intrarow space, the genotypes responded differently in plant height. Early in maturity and tall in stature Japanese cultivars responded to plant density altered by interrow space stronger than super-early and short Polish genotypes. In the intrarow space experiment, the relation were reversed, viz. the Polish genotypes turned to be more responsive to plant density than Japanese cultivars. Moreover, the Japanese cultivars (both narrow leaflet type) tended rather to reduce than increase plant height with decreased intrarow space. Probably in the case of intrarow experiment in 1988 the Japanese cultivars did not meet all their environmental requirements (light, nutrients, etc.) and could not activate their full plant growth potential. Underdeveloped plant height of genotypes involved in 1988 experiment (intrarow space) may explain reverse tendency in plant height of Japanese cultivars. Specific response of genotypes to interrow and intrarow space was found in reports of Hicks et al. (1969), Wilcox (1974), Green et al. (1977), Lueschen and Hicks (1977), and Hoggard et al. (1978). Above findings indicate that plant height is genetically very complicated characteristic. It depends on many factors (year, location,

weather conditions, etc.) which involved with plant density and planting geometry make the results difficult to explain.

Branch number depends mainly on genotype potential to grow and plant density. Fontes and Ohlrogge (1972) stated that at high plant densities (intrarow space altered), the plants grew in mutual shadow which stimulates main stem elongation and retards developing lateral branches and stem diameter and slows dry weight accumulation. Relatively short in stature and super-early maturing Polish genotypes utilized available interrow space by producing more branches than Japanese cultivars and that led to their higher yield productivity and efficiency. The results reported by Lehman and Lambert (1960), Green et al. (1977), Lueschen and Hicks (1977) and Costa et al. (1980) showed similar soybean response to row width as was found in the present study for the Polish and Japanese genotypes.

Regarding stem diameter the findings of Hicks et al. (1969) and Fontes and Ohlrogge (1972) confirmed present experiments. Thinner stems and higher lodging score in high density plots explained the importance of stem strength of genotypes planted in high density populations. Cooper (1971) noticed that lodging might be important factor in preventing yield increases from narrower rows. In narrow interrow space the super-early genotypes did not increase their lodging scores though the early Japanese cultivars were susceptible to lodging. The stem of super-early genotypes is specific type, which effectively prevents early lodging in the narrow

interrow space. The Polish genotypes lodged relatively later and this could prevent their yields from losses in the high plant density. It is evident that genotypes with the same or similar stem diameters differ in the lodging score. It means that other factors, e.g. stem strength, branch number, their length, biomass, etc. may contribute to lodging resistance substantially. Specific reaction of 'Wasekogane' to interrow and intrarow space showed that the decrease in stem diameter with changes in other characteristics (biomass, height, stem diameter etc.) may prevent plants from lodging even in high plant density. The increase in lodging susceptibility in more dense populations was reported by Wilcox (1974), Hoggard et al. (1978) and Costa et al. (1980). It seems that super-early cultivars selected for cultivation in high plant densities should have well developed main stem, able to protect them against lodging.

From the standpoint of basal pod height the Japanese cultivars should be cultivated in spacious plant arrangement, because in overpopulated environment substantial part of their canopy did not produce pods. Opposite can be stated about super-early genotypes. They should be cultivated in relatively dense planting (interrow and intrarow reduced) for increasing plant height and correlated with it basal pod height and generally shifting pod production up on the stature. Similar findings were reported by Costa et al. (1980). In the pod number on bottom parts of plant stature the Polish genotypes were more responsive to plant density altered by

both interrow and intrarow space than Japanese cultivars. It is general tendency that super-early soybean genotypes set basal pods low. Japanese genotypes responded weakly because they habitually set basal pods relatively high. Present results confirmed data of Hicks et al. (1969), Wilcox (1974), Beaver and Johnson (1981), and Hartung et al. (1981).

Decreased interrow and intrarow space reduced both stem and branch weight. However, when the ratio of stem weight to combined weight of stem and branches was considered, it was obvious that branch weight decreased greater than stem. Differences were observed among genotypes, too. Reduction in branch weight of super-early genotypes was smaller than of early genotypes. Opposite relations were observed in the stem weight.

In seed yield per plant and its components, the Polish genotypes were more responsive to interrow space and the Japanese cultivars ('Wasekogane' and 'Suzuhime') were more responsive to intrarow space. This showed that super-early genotypes could be more responsive to the interrow space and the early maturing genotypes could be more sensitive to intrarow space. Moreover, the response to interrow space could vary among Polish genotypes and not among Japanese cultivars. Different response to interrow and intrarow space indicated that there exists considerable potential of variability in the tested genotypes for creating new cultivars able to yield effectively in a range of interrow and intrarow spaces. Reports of Lehman and Lambert (1960), Harris (1967),

Hicks et al. (1969), Cooper (1971), Wilcox (1974), Green at al. (1977), Costa et al. (1980), and Johnson (1987), showed different response of seed yield depending on field conditions, maturity, and plant height.

Harvest index characterizes the relation of seed yield to above ground biomass of particular genotype. It showed small changes in increased density and no any specific response of particular genotypes. Generally, it was in agreement with report of Buzzel and Buttery (1977).

The data concerning seed and pod number per plant confirmed the results obtained by Lehman and Lambert (1960). The insensitivity of seed size to plant density was confirmed by its high heritability in interrow space and by low regression coefficients in the intrarow space experiment. The independence of seed size over a range of plant densities was reported by Wilcox (1974), Green et al. (1977), and Stivers and Swearingin (1980). Conflicting data were reported by Costa et al. (1980) viz. increased plant density increased hundred seed weight. Above delivered data proved that characteristics contributing to seed yield are extremely complex and depends highly on interrelations between genotype and many of environmental factors.

VI. Response to additional space occurred at different stages of plant development

1. Introduction

Soybean after seeding is exposed to various hazards. Some may come from unfavorable soil conditions like excess or lack of moisture, soil bed compactness, low temperatures, etc. Other may be caused by pests (diseases, leaf eating insects, birds, etc.), herbicides, weather conditions (late spring frost or snow, hail, etc.), mechanical damages during interrow tillage and weeding and so on. Such hazards may occur during the plant development. Some of them may kill a number of plants causing stands in a row uneven (skips, gaps, missing plants, etc.). Poorly emerged or damaged soybean stands are often replanted without taking the yield compensating ability of the plants in the field into consideration (Pepper and Walker, 1988).

As it was mentioned in previous chapter soybean has an enormous potential for filling available space and also considerable compensation ability for a number of damaged or missed plants (Probst, 1945; Pandey and Torrie, 1973; Stivers and Swearingin, 1980; Pepper and Walker, 1988).

Along with developmental processes the plant potential

for compensation may depend on their genotypic background. Super-early and early genotypes have different growing patterns. It could impose some limitations on ability to compensate losses in the plant stand during early stages of plant development. Super-early maturing and short stature genotypes may be different in compensation ability from early, intensively growing genotypes.

The purpose of this chapter was to evaluate the compensating ability of super-early soybean cultivars for additional space occurred by thinning alternate hills in the different stages of plant development. By means of analysis of variance with regression and stability parameters the compensation ability of Polish and Japanese genotypes was examined.

2. Materials and methods

Plant materials used were as follows. In 1987, Polish cultivars: 'Polan' and 'Progres', Polish breeding lines: 'IHAR-NK', 'AR1', 'S23', 'R18', and Japanese cultivars: 'Kitahomare', 'Toyosuzu', 'Suzuhime', 'Kitamishiro', 'Okuhara', 'Wasekogane'. In 1988, Polish genotypes: 'Polan', 'Progres', 'AR1', 'S23', and Japanese cultivars: 'Suzuhime' and 'Wasekogane'.

Experimental methods were as follows. In 1987, a split-plot experimental design with three replications was applied. Treatments were assigned to the main plots and the genotypes to the subplots.

Subplots were arranged in three row units. Rows were

1.0 m long. Interrow space was 50 cm. Space in the row was adjusted to obtain two levels of population density: 80 plants/m^2 and 40 plants/m^2. Sowing was done on May 21. At harvest, five plants fully matured were sampled from every plot for biometrical evaluation.

Following treatments were studied.

a) 40 plants/m^2 - control (full stand)

b) thinning from 80 to 40 plants/m^2 at V-3

c) thinning from 80 to 40 plants/m^2 at V-5

d) thinning from 80 to 40 plants/m^2 at V-8

e) 80 plants/m^2 - control (full stand)

In 1988, a split-plot experimental design with three replications was applied. The stages of plant development were assigned to the main plots, and genotypes to the sub-plots. One replication was damaged by herbicide drift and excluded from statistical calculations.

Plots consisted of three rows 50 cm apart. Planting densities were controlled by changing interhill space (5, 10, and 20 cm). On May 27, plots were sown with four seeds per hill and thinned to two plants per hill after emergence. During plant growth the alternate hills (50% of plant population) were removed manually at V-3 and V-6 stages.

For quantitative recordings ten plants fully matured were sampled from each plot of two replications.

Following treatments were studied.

a) 20 plants/m^2 - control (full stand)

b) thinning from 40 to 20 plants/m^2 at V-3

c) thinning from 40 to 20 plants/m^2 at V-6

d) 40 plants/m^2 - control (full stand)

e) thinning from 80 to 40 plants/m^2 at V-3

f) thinning from 80 to 40 plants/m^2 at V-6

g) 80 plants/m^2 - control (full stand)

Statistical analyses were done separately for the 'low density' segment a-d (40 plants/m^2 thinned to 20 plants/m^2) and the 'high density' segment d-g (80 plants/m^2 thinned to 40 plants/m^2).

Statistical analyses were done according to the description by Finlay and Wilkinson (1963) developed and adapted with details by Eberhart and Russell (1966) and Shimamoto and Hosokawa (1977). In this study the thinning stages were treated as the locations in above mentioned reports. Such arrangements of analysis of variance with regression allowed to find genotypes with stable performing in the different thinning stages.

3. Results

In 1987 no meaningful variation was recorded in the phenological characteristics.

In 1988, regarding harvest maturity, difference among thinning stages in the low density was found, but no 'genotype x thinning stage' interaction was detected. Plants tended to delay maturity when thinning was done in later stages of growth. In the high density populations only geno-

type effect was observed.

In 1987, plant canopy tended to close earlier when thinning was done in later stages of plant development. However, treatment, genotype and interaction effects were not detected. In 1988, plants did not attained to full canopy closure. Yet, the Japanese cultivars shadowed the interrows more than Polish genotypes.

The analysis of variance (Table VI-1) indicated that the effects of thinning stage and genotypes were found except the lodging score which was significant only in 1987. The 'genotype x thinning stage' interactions were observed in plant height, branch number and stem diameter in 1987. The pooled deviations were found in branch number in 1987 (Table VI-1).

In both years, soybean grew markedly taller in the stature and produced less branches when thinning was done in the later stages of plant development (Fig. VI-1 and VI-2). On the average, in plant height and branch number, the Polish genotypes were more responsive to thinning stages than Japanese cultivars. In plant height 'Wasekogane' and 'Suzuhime' showed the highest stability and 'AR1' and 'Okuhara' were highly responsive (Table VI-2). In branch number, a weak response to thinning in various stages was noticed in 'Kitamishiro' and 'AR1'; the strong response was recorded in super-early cultivars 'Polan' and 'Progres' (Table VI-2).

Stem diameter tended to decrease when thinning was done in later stages of plant development (Fig. VI-3). In 1987, except 'Suzuhime' and 'Kitamishiro' the Japanese cultivars

Table VI-1. Variance analysis of morphological characteristics, lodging score, mature plant weight and its components, and harvest index in populations with removed 50% of plants at stages V-3, V-5 and V-8 of plant development in 1987, and at stages V-3 and V-6 in low and high densities in 1988

Source of variance	d.f.*	Plant height	Stem diameter	Branch number	Lodging	Weight of: mature plant	Weight of: stem and branches	Weight of: stem	Weight of: branches	Harvest index
1987										
a	1	**	**	**	**	**	**	**	**	**
b	11	**	**	**	**	**	**	**	**	**
c	11	**	**	**	ns	**	**	**	**	*
d	36	ns	**	ns	ns	**	ns	*	ns	**
e	2	**	**	ns	ns	**	*	ns	**	**
f	118	15.8	4.2	10.2	8.0	69.0	14.3	12.0	1.6	2.3
1988 - low density										
a	1	**	**	**	ns	**	**	**	**	**
b	5	**	**	**	**	**	**	**	**	*
c	5	ns	ns	ns	ns	ns	ns	**	ns	ns
d	12	ns	ns	ns	ns	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
f	23	9.4	21.2	71.0	11.6	6.5	28.3	7.8	10.7	32.3
1988 - high density										
a	1	**	**	**	ns	**	**	**	**	**
b	5	**	**	**	**	*	**	**	**	*
c	5	ns	ns	ns	ns	ns	*	**	**	*
d	12	ns	ns	ns	ns	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
f	23	12.9	13.2	9.4	2.6	2.6	8.3	4.5	1.1	10.3

Notes:
* degrees of freedom
a linear regression (treatment), tested against c or f
b genotypes, tested against c or f
c genotype x treatment interaction, tested against d
d pooled deviations, tested against f
e replications, tested against f
f error, mean square

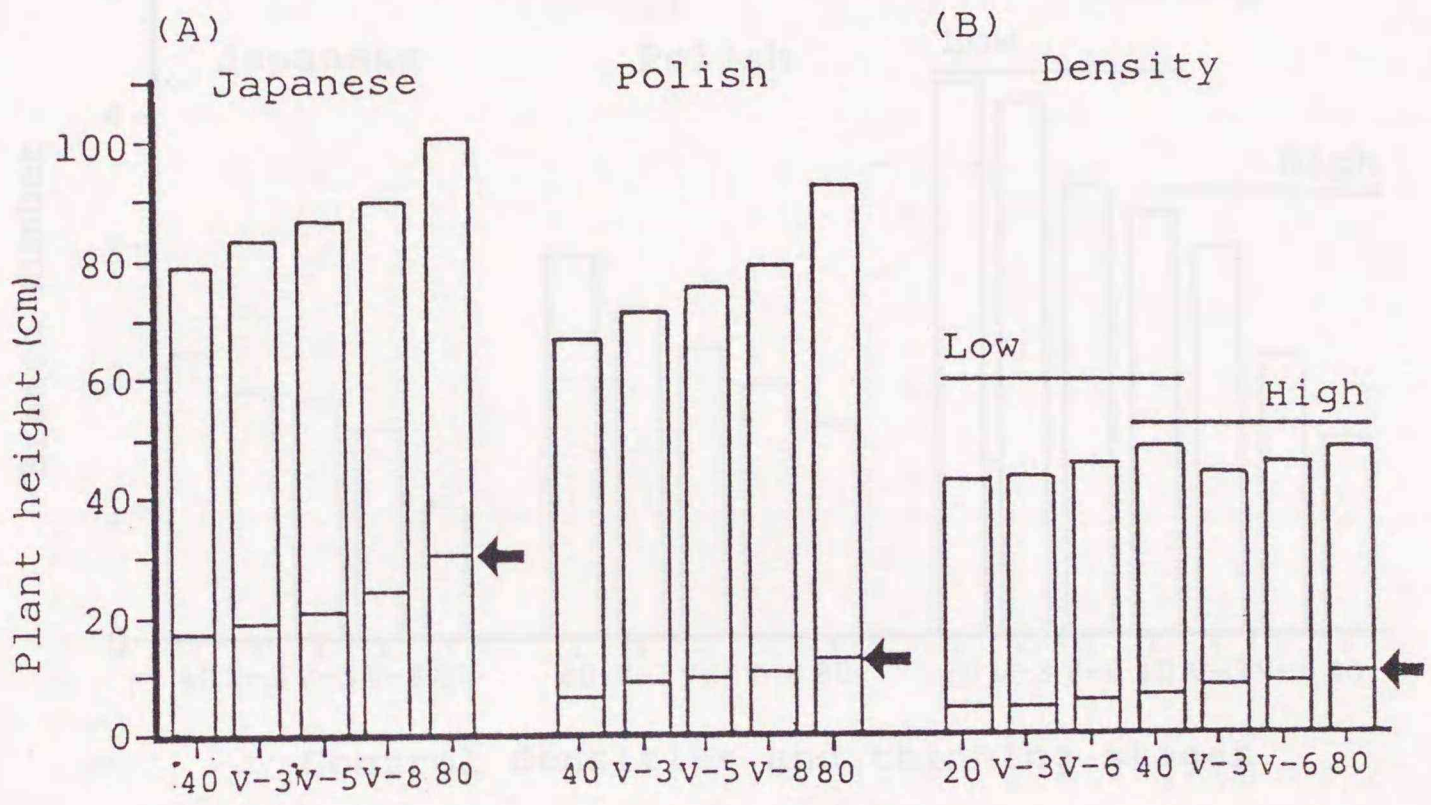


Fig. VI-1. Plant height and basal pod height in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

← Basal pod height

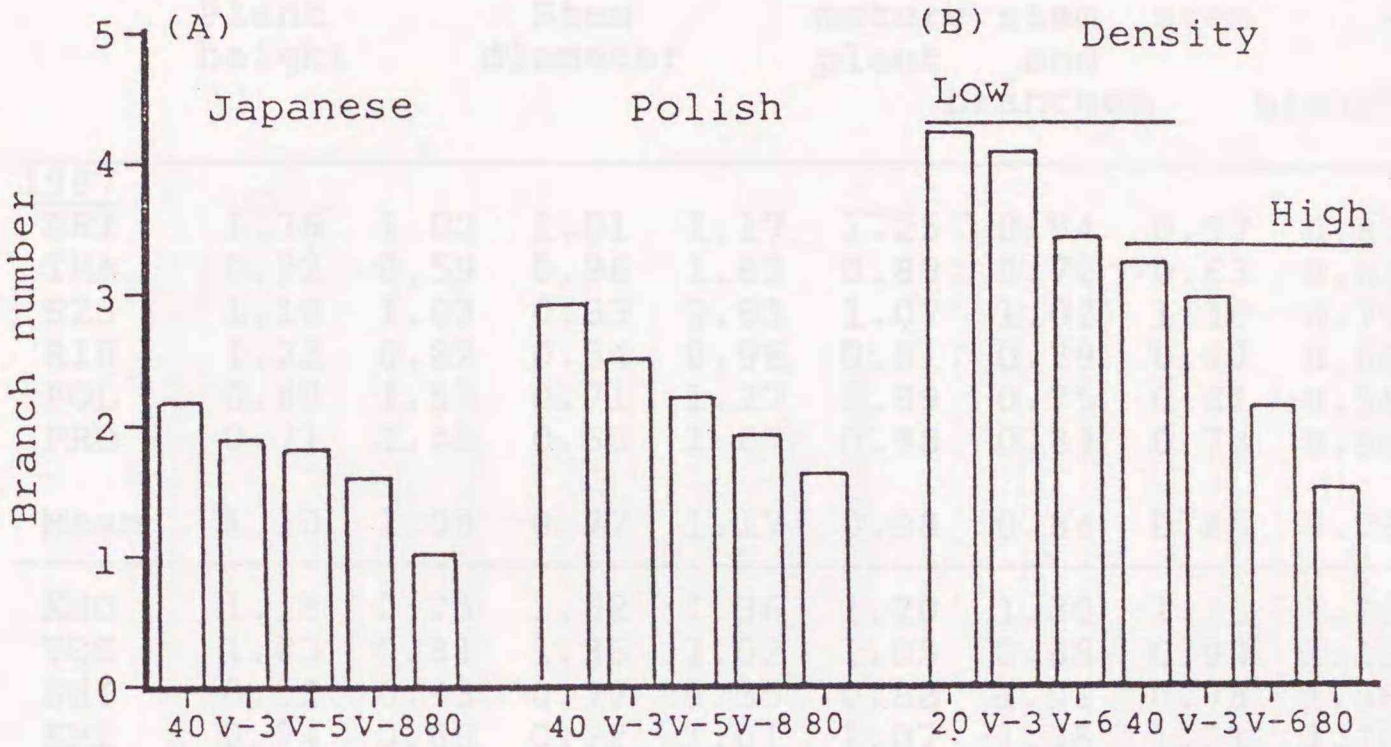


Fig. VI-2. Branch number in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

Table VI-2. Stability parameters of morphological characteristics, lodging score, mature plant weight and its components, and harvest index in populations with removed 50% of plants at stages V-3, V-5 and V-8 of plant development in 1987, and at stages V-3 and V-6 in low and high densities in 1988

Genotype	Plant height	Branch number	Stem diameter	Lodging	Weight of mature plant	Weight of stem and branches	Weight of stem	Harvest index	
1987									
AR1	1.76	1.02	1.01	1.17	1.25	0.94	0.97	0.87	0.53
IHA	0.92	0.59	0.96	1.62	0.89	0.72	0.63	0.83	-0.56
S23	1.18	1.02	0.83	0.91	1.07	1.02	1.10	0.77	-0.04
R18	1.22	0.82	0.54	0.96	0.81	0.79	0.87	0.66	0.75
POL	0.80	1.57	0.71	1.27	0.89	0.75	0.81	0.56	-0.71
PRO	0.71	1.45	0.60	1.07	0.98	0.83	0.73	0.96	1.43
Mean	1.10	1.08	0.77	1.17	0.98	0.84	0.85	0.78	0.24
KHO	1.18	0.75	1.82	1.36	1.20	1.30	1.36	1.23	4.85
TOS	1.03	0.81	1.36	1.02	1.05	0.88	0.90	1.12	-1.42
SHI	0.52	0.93	0.77	0.35	0.88	1.01	0.78	1.56	3.27
KMI	0.74	0.68	0.72	1.01	1.07	1.38	1.21	1.70	0.23
OKU	1.56	1.17	1.58	1.05	0.91	0.91	0.78	1.08	0.60
WKO	0.37	1.20	1.11	0.20	1.00	1.47	1.86	0.65	3.06
Mean	0.90	0.92	1.23	0.83	1.02	1.16	1.15	1.22	1.76
LSD 5%	0.35	0.59	0.63	ns	0.31	0.43	0.81	0.48	5.79
1988 - low density									
AR1	0.64	1.31	1.84	0.00	1.28	1.63	1.85	1.59	-0.08
S23	1.87	1.47	0.59	-3.00	0.72	0.38	0.33	0.73	2.04
POL	1.12	1.11	0.79	0.00	1.07	0.76	-1.26	0.98	1.67
PRO	1.11	0.46	0.72	6.00	0.64	0.41	-0.20	0.61	0.38
WKO	0.48	0.98	0.78	0.00	1:06	1.21	3.82	0.98	0.77
SHI	0.78	0.67	1.29	3.00	1.22	1.61	1.45	1.10	1.22
LSD 5%	ns	ns	ns	ns	ns	ns	1.60	ns	ns
1988 - high density									
AR1	0.40	1.08	0.29	0.23	0.72	0.43	0.05	0.94	1.26
S23	1.53	0.69	1.01	0.92	0.88	0.96	0.94	0.83	1.13
POL	1.74	0.99	1.08	1.62	0.71	0.70	0.79	0.63	0.82
PRO	0.93	1.25	0.83	2.31	1.02	0.77	0.67	0.90	0.21
WKO	0.40	0.80	1.45	0.00	1.12	1.28	1.48	0.97	2.43
SHI	1.00	1.19	1.34	0.92	1.54	1.87	2.07	1.73	0.14
LSD 5%	ns	0.40	ns	ns	ns	0.94	1.28	0.50	1.46

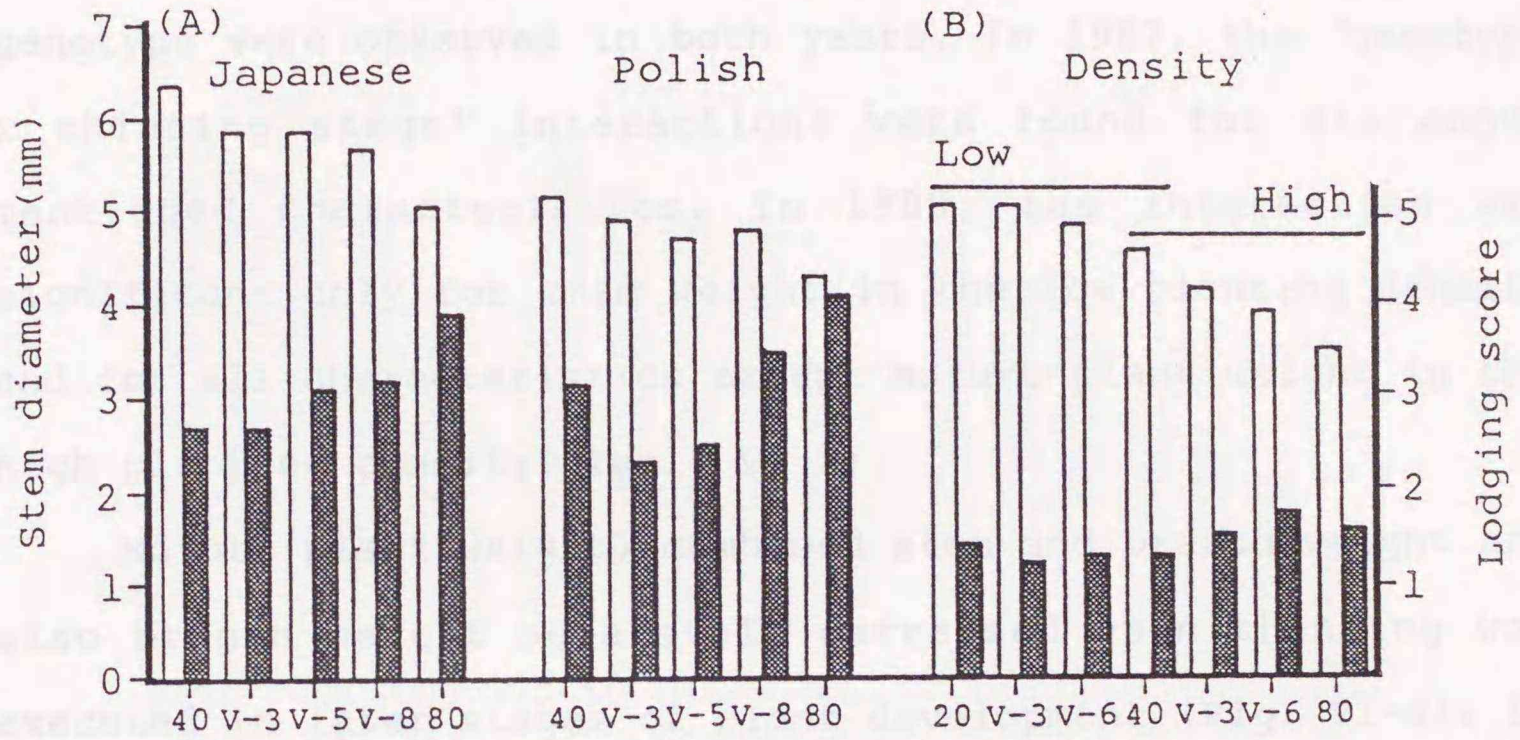


Fig. VI-3. Stem diameter and lodging score in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

were more responsive to thinning stages than the Polish genotypes. 'Kitahomare', 'Okuhara' and 'Toyosuzu' were intensively responsive and 'R18' and 'Progres' were remarkably stable (Table VI-2).

In mature plant weight, stem and branch weight taken together and separately, the effects of thinning stage and genotype were observed in both years. In 1987, the 'genotype x thinning stage' interactions were found for all above mentioned characteristics. In 1988, the interaction was significant only for stem weight in the low planting density and for all characteristics except mature plant weight in the high planting density (Table VI-1).

Mature plant weight, combined stem and branch weight and also branch weight separately decreased when thinning was executed in later stages of plant development (Fig. VI-4). In 1987, in mature plant weight the response of 'AR1' and 'Kitahomare' was great but the other Polish and Japanese genotypes showed similar sensitivity (Table VI-2). In stem weight, the effects of thinning at different stages of plant development were smaller in the Polish than Japanese genotypes. 'Wasekogane' and 'Kitahomare' were especially sensitive, and 'IHAR-NK' and 'Progres' were rather tolerant to thinning stages (Table VI-2). The Polish group of genotypes showed steady decrease in stem weight (Fig. VI-4). In 1988, 'Wasekogane' in the low density, and also 'Suzuhime' in the high density appeared to be most sensitive to thinning stages

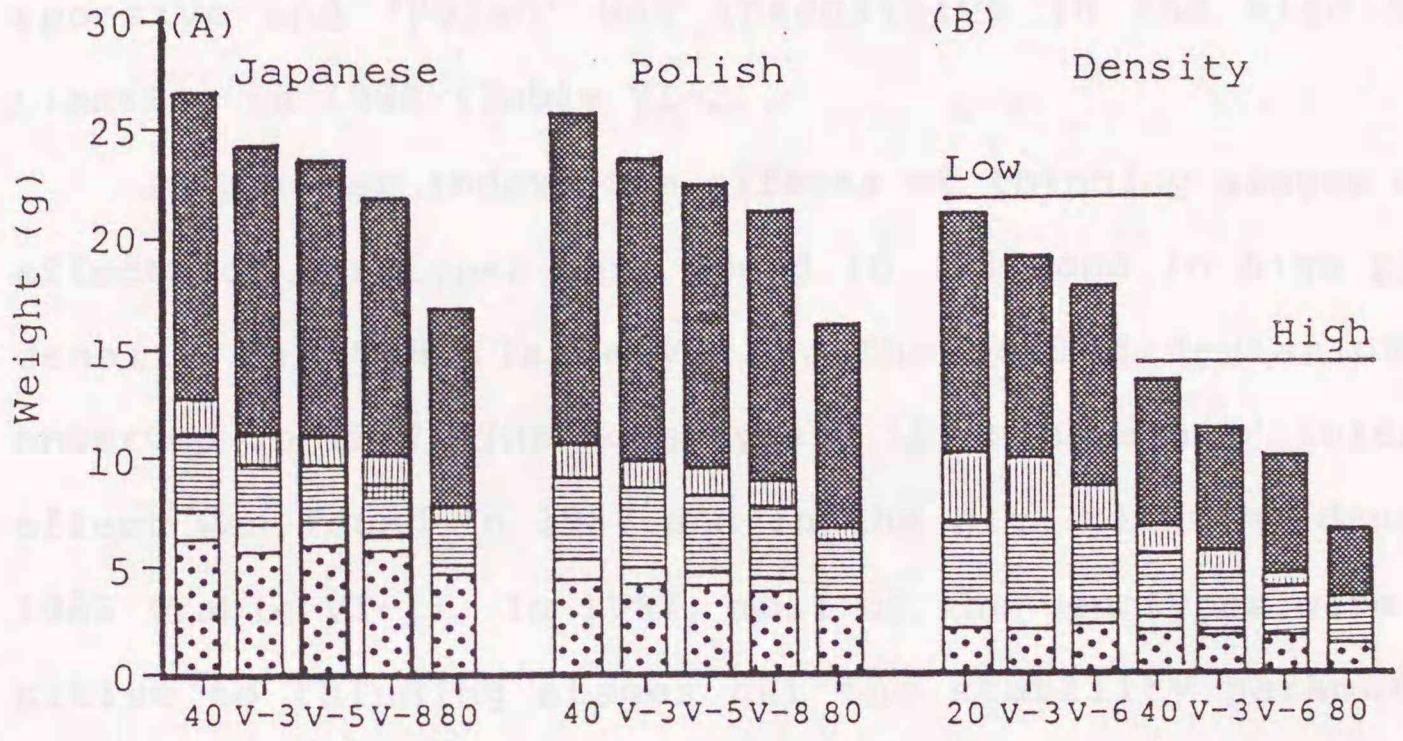


Fig. VI-4. Mature plant weight and its components in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

- Seed yield
- Weight of pods on stem
- Weight of pods on branches
- Branch weight
- Stem weight

(Table VI-2).

In 1987, in branch weight, the Japanese cultivars except 'Wasekogane' responded more strongly to thinning stages than Polish genotypes. 'Kitamishiro' and 'Suzuhime' were highly responsive and 'Polan' and 'Wasekogane' were insensitive to thinning stages in 1987 and also 'Suzuhime' was highly responsive and 'Polan' was insensitive in the high density planting in 1988 (Table VI-2).

In harvest index, the effects of thinning stages and the effects of genotypes were found in 1987 and in high planting density in 1988 (Table VI-1). The pooled deviations were observed in 1987. The 'genotype x thinning stage' interaction effect was found in 1987 and in the high planting density in 1988 (Table VI-1). In 1987, most of the genotypes were insensitive to thinning stages but the stability parameters of three Japanese cultivars, 'Kitahomare', 'Suzuhime' and 'Wasekogane' were relatively great. In 1988, in the high density, 'Wasekogane' also was sensitive, where 'Suzuhime' and 'Progres' turned to be insensitive to thinning stages (Table VI-2).

In 1987, in the characteristics of pod distribution on bottom parts of plant stature, except the pooled deviation in ratio of pod number below 15 cm all other effects were found (Table VI-3). In 1988, most of the effects of thinning stages and genotype effects were observed in both densities (Table VI-3). The 'genotype x thinning stage' interactions were found in the number of pods below 10 cm and all three ratios

Table VI-3. Variance analysis of characteristics of pod distribution on bottom parts of plant canopy in populations with removed 50% of plants at stages V-3, V-5 and V-8 of plant development in 1987, and at stages V-3 and V-6 in low and high densities in 1988

Source of variance	d.f.*1	Basal pod height		Pod number below 10 cm		Pod number below 15 cm		Pod number below plant half	
			%*2		%*3		%*3		%#3
1987									
a	1	**	**	**	**	**	**	**	**
b	11	**	**	**	**	**	**	**	**
c	11	**	**	**	**	**	**	**	**
d	36	**	**	**	**	**	ns	**	**
e	2	**	**	ns	ns	ns	*	**	**
f	118	131.4	2.3	2.9	2.7	19.9	2.3	92.1	14.4
1988 - low density									
a	1	**	**	**	**	**	**	**	ns
b	5	**	**	**	**	**	**	**	**
c	5	ns	ns	*	*	ns	*	ns	*
d	12	ns	ns	ns	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns	ns
f	23	9.8	6.5	1.4	10.5	2.6	21.6	8.1	19.2
1988 - high density									
a	1	**	**	**	**	**	**	**	**
b	5	**	**	**	**	**	**	**	ns
c	5	ns	ns	ns	ns	ns	ns	ns	ns
d	12	ns	ns	ns	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns	ns
f	23	23.2	12.4	9.9	23.7	1.5	27.3	3.1	23.1

Notes:
*1 degrees of freedom
*2 ratio to plant height
*3 ratio to total pod number/plant
a linear regression (treatment), tested against c or f
b genotypes, tested against c or f
c genotype x treatment interaction, tested against d
d pooled deviations, tested against f
e replications, tested against f
f error, mean square

in the low planting density and nothing in the high planting density in 1988 (Table VI-3).

Basal pod height tended to increase when thinning was done in later stages (Fig. VI-1). On the average, in 1987, the response to thinning stages of Polish genotypes was smaller than that of the Japanese ones. In the Polish genotypes the stability parameters were relatively small. In the Japanese cultivars the stability parameters were various with exceptionally great in 'Kitahomare', 'Kitamishiro' and 'Okuhara' (Table VI-4).

In 1987, the Japanese genotypes produced a few pods below 10 and 15 cm of plant height (Fig. VI-5). Polish genotypes decreased pod setting below 10 and 15 cm when thinned in later stages. Among Polish genotypes only 'IHAR-NK' showed relatively low sensitivity and other genotypes were more responsive in pod number below 10 and 15 cm of plant height. In 1988, in the low density planting, 'Suzuhime' and 'S23' proved to be a stable and sensitive genotypes regarding the pod number below 10 cm of plant height and its ratio, respectively (Table VI-4).

Pod number below half of plant height decreased when thinned in later stages (Fig. VI-5). On the average, the response to thinning stages of plant development was stronger in Polish than in Japanese genotypes. In ratio of pod number below half of plant height, the average response of Japanese cultivars was stronger than Polish genotypes. Some genotypes, for example 'Okuhara' and 'Kitamishiro', showed relatively

Table VI-4. Stability parameters of characteristics of pod distribution on bottom parts of plant canopy in populations with removed 50% of plants at stages V-3, V-5 and V-8 of plant development in 1987, and at stages V-3 and V-6 in low and high densities in 1988

Genotype	Basal pod		Pod number below					
	height	%*1	10 cm	%*2	15 cm	%*2	plant half	%*2
1987								
AR1	0.62	0.51	3.04	2.59	2.27	1.83	1.49	1.62
IHA	0.77	0.90	0.88	1.10	0.99	1.36	1.15	0.48
S23	1.06	1.29	1.89	1.94	2.58	2.95	1.26	0.36
R18	0.44	0.13	1.37	1.22	1.74	1.72	1.65	1.63
POL	0.51	0.77	2.47	2.50	1.57	1.22	1.05	1.18
PRO	0.47	0.80	1.78	1.68	1.27	0.35	0.72	-0.08
Mean	0.65	0.73	1.90	1.84	1.74	1.57	1.22	0.87
KHO	1.91	1.54	0.00	0.00	0.20	0.35	0.58	-0.38
TOS	1.04	0.66	0.16	0.28	0.20	0.43	0.53	0.79
SHI	0.76	0.98	0.00	0.00	0.41	0.49	0.92	1.16
KMI	1.82	1.81	0.00	0.00	0.00	0.00	0.80	2.04
OKU	1.82	1.45	0.05	0.08	0.17	0.32	0.94	2.57
WKO	0.76	1.16	0.36	0.60	0.58	0.98	0.90	0.64
Mean	1.35	1.27	0.10	0.16	0.26	0.43	0.78	1.13
LSD 5%	0.58	0.97	0.44	0.63	0.45	0.75	0.69	2.07
1988 - low density								
AR1	1.32	1.88	1.20	-0.07	1.16	-0.17	1.00	-4.27
S23	0.77	-0.18	1.49	2.23	1.41	2.14	1.16	3.29
POL	1.38	1.83	1.14	1.66	1.04	1.20	1.06	3.28
PRO	0.68	0.83	0.93	1.16	0.86	1.28	0.60	1.19
WKO	0.86	0.89	0.92	0.64	0.93	0.78	1.26	2.41
SHI	0.99	0.75	0.33	0.38	0.60	0.77	0.91	0.10
LSD 5%	ns	ns	0.64	1.66	ns	ns	ns	ns
1988 - high density								
AR1	0.67	0.66	1.22	1.02	1.00	0.92	0.97	1.10
S23	0.86	1.15	0.94	0.61	1.03	0.80	1.12	1.13
POL	0.86	0.76	1.15	1.41	1.05	1.42	0.77	1.07
PRO	1.41	1.28	1.54	1.75	1.37	1.52	1.01	1.05
WKO	1.18	1.14	0.88	0.97	0.79	0.66	0.89	0.88
SHI	1.03	1.00	0.28	0.24	0.75	0.69	1.23	0.76
LSD 5%	ns	ns	ns	ns	ns	ns	ns	ns

Notes:
*1 ratio to plant height
*2 ratio to total pod number/plant

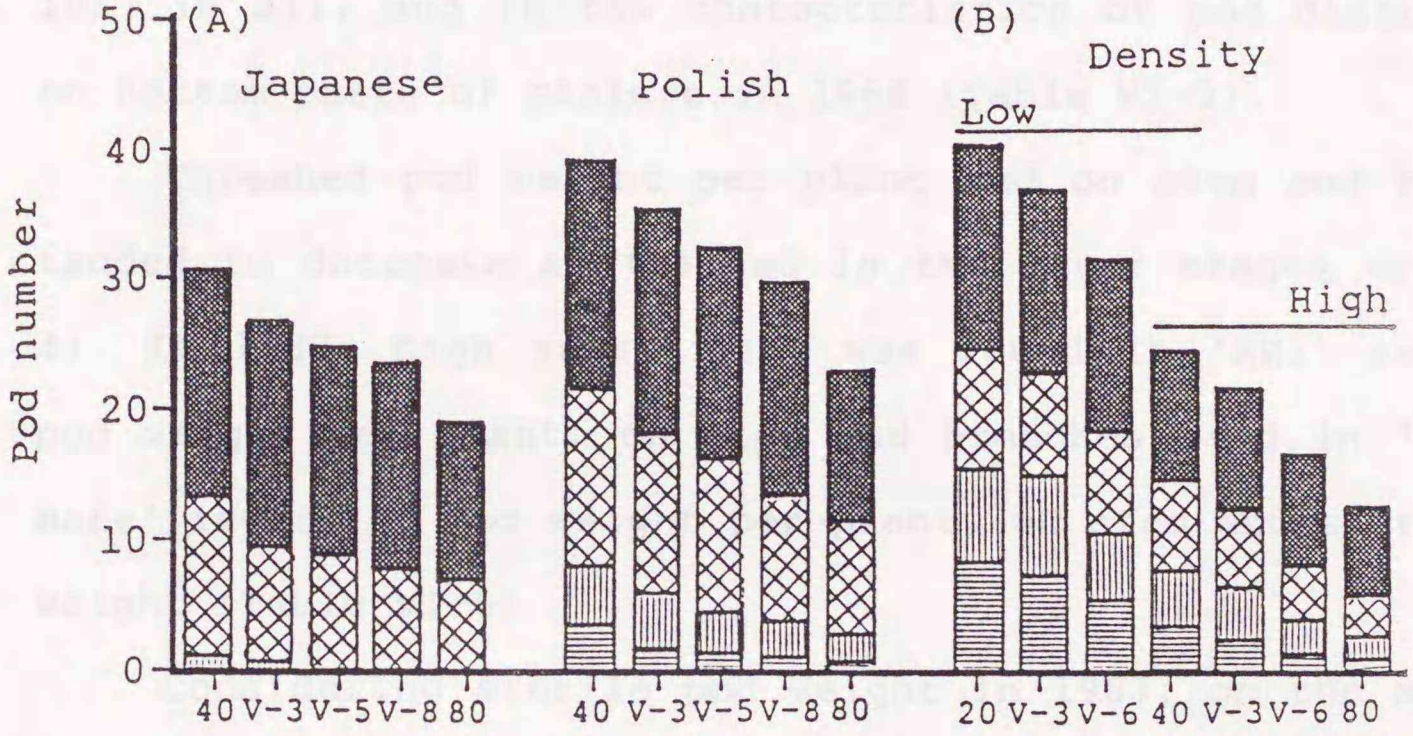


Fig. VI-5. Pod distribution along plant canopy height in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

great difference between stability parameters in pod number below half of plant height and its ratio (Table VI-4).

Regarding threshed pod weight per plant and its components, and weight per pod the effects of thinning stage and genotype were observed in 1987 and in both densities in 1988. The 'genotype x thinning stage' interactions were found in 1987 in all, and in few characteristics of pod distribution on bottom parts of stature in 1988 (Table VI-5).

Threshed pod weight per plant and on stem and branches tended to decrease as thinned in the later stages (Fig. VI-4). In 1987, high sensitivity was found in 'AR1' regarding pod weight per plant, on stem and branches, and in 'Kitahomare' regarding pod weight per plant, on stem and sterile pod weight (Table VI-6).

Considering sterile pod weight in 1987, on the average, the response to thinning stages was more differentiated among Japanese cultivars than among Polish genotypes. Especially sensitive were 'Kitahomare' and 'Kitamishiro' but 'Wasekogane' was very stable. 'Okuhara' responded to thinning stages reversely when compared to other genotypes (Table VI-6). In 1988, 'AR1' in both densities and 'S23' in the high planting density were highly sensitive. 'Wasekogane' was stable in both years, because of its small weight of sterile pods (Table VI-6).

In 1987, regarding threshed weight per pod and weight per pod on branches the Polish genotypes, on the average, were more and, regarding weight per pod on stem less stable

Table VI-5. Variance analysis of threshed pod weight and weight per pod in populations with removed 50% of plants at stages V-3, V-5 and V-8 of plant development in 1987, and at stages V-3 and V-6 in low and high densities in 1988

Variance source	d.f. *	Pod weight			Weight per pod			
		plant	branches		overall	branches		
			stem	sterile		stem		
1987								
a	1	**	**	**	**	**	**	**
b	11	**	**	**	**	**	**	**
c	11	**	**	**	**	**	*	**
d	36	**	**	**	ns	ns	**	ns
e	2	*	ns	**	ns	ns	ns	**
f	118	15.0	11.3	1.6	4.6	224.3	396.6	313.6
1988 - low density								
a	1	**	**	**	**	*	**	*
b	5	**	**	**	**	**	**	*
c	5	ns	ns	ns	*	ns	**	ns
d	12	ns	ns	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns
f	23	10.7	31.6	41.8	3.0	706.5	739.2	813.7
1988 - high density								
a	1	**	**	**	**	*	**	**
b	5	**	**	**	*	**	*	**
c	5	ns	ns	ns	*	ns	ns	*
d	12	ns	ns	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns
f	23	3.2	2.0	5.3	1.0	350.3	576.9	247.7

Notes:
* degrees of freedom
a linear regression (treatment), tested against c or f
b genotypes, tested against c or f
c genotype x treatment interaction, tested against d
d pooled deviations, tested against f
e replications, tested against f
f error, mean square

Table VI-6. Stability parameters of threshed pod weight and weight per pod in populations with removed 50% of plants at stages V-3, V-5 and V-8 of plant development in 1987, and at stages V-3 and V-6 in low and high densities in 1988

Genotype	Pod weight				Weight per pod		
	plant	branches			overall	branches	
		stem	sterile			stem	
1987							
AR1	1.41	1.38	1.48	0.91	2.28	3.47	-0.09
IHA	0.95	0.93	0.96	0.94	3.24	2.99	2.77
S23	0.82	0.80	0.83	0.96	-1.94	-1.56	0.02
R18	0.73	0.60	0.89	0.67	0.07	0.97	-0.08
POL	0.94	0.96	0.97	0.98	-0.01	0.34	0.62
PRO	0.88	0.96	0.79	0.67	0.88	1.02	0.49
Mean	0.95	0.94	0.99	0.86	0.75	1.21	0.62
KHO	1.51	1.81	0.90	3.03	1.27	0.09	1.15
TOS	1.06	1.05	1.03	1.06	0.12	1.04	-0.20
SHI	0.97	0.65	1.38	1.23	0.15	-0.04	1.62
KMI	0.72	0.70	0.63	1.98	0.68	2.23	-0.42
OKU	0.94	1.09	0.97	-0.69	1.28	-2.07	1.58
WKO	1.07	1.06	1.16	0.25	3.97	3.53	4.53
Mean	1.05	1.06	1.01	1.14	1.25	0.79	1.38
LSD 5%	0.50	0.81	0.48	0.90	2.75	4.58	1.20
1988 - low density							
AR1	1.11	0.96	1.33	3.67	0.35	-0.14	0.66
S23	1.06	1.23	1.09	0.29	1.29	2.94	1.08
POL	1.11	1.07	1.04	1.38	1.98	1.82	2.10
PRO	0.63	0.41	0.70	-0.07	0.43	0.22	0.85
WKO	1.05	1.72	0.86	0.10	1.45	1.09	0.13
SHI	1.04	0.60	0.99	0.62	0.51	0.06	1.17
LSD 5%	ns	ns	ns	2.78	ns	1.60	ns
1988 - high density							
AR1	0.82	0.72	0.95	2.48	0.69	1.01	-0.10
S23	0.96	0.93	0.99	2.20	0.96	0.74	1.66
POL	0.70	0.74	0.66	-0.12	1.21	1.00	1.30
PRO	1.08	0.99	1.19	1.43	1.51	1.29	2.14
WKO	1.08	1.17	0.96	-0.34	0.97	1.12	0.51
SHI	1.35	1.45	1.24	0.36	0.65	0.84	0.49
LSD 5%	ns	ns	ns	1.99	ns	ns	2.06

than Japanese cultivars (Table VI-6). In the weight per pod, 'IHAR-NK' and 'Wasekogane' were highly sensitive to thinning stages. 'Polan', 'R18', 'Toyosuzu' and 'Suzuhime' were relatively stable throughout the thinning stages. In weight per pod overall and on stem the response of 'S23' to thinning stages was reverse when compared with other genotypes (Table VI-6). In 1988, in the low density, weight per pod of 'S23' and 'Suzuhime' were the most responsive and stable genotypes, respectively. In the high density in weight per pod on branches, 'Progres' and 'AR1' were the most and least sensitive genotypes, respectively (Table VI-6).

Regarding seed yield and its components (Table VI-7), the thinning stage effect was found except seed number per pod in the low density in 1988. The genotype effect was observed in both experiments. In 1987, the 'genotype x thinning stage' interactions were found in most of the yield characteristics (Table VI-7). In 1987, the pooled deviations were found except one hundred seed weight and sterile pod number. In 1988, in the high density, the pooled deviations were observed only for sterile pod number per plant (Table VI-7).

Seed yield per plant was inevitably decreasing when thinned in later stages (Fig. VI-4). In 1987, 'Wasekogane' was the most stable cultivar, 'AR1' and 'S23' showed greater sensitivity to thinning stages and other super-early genotypes were moderate (Table VI-8).

In 1987, daily seed yield efficiency steeply decreased

Table VI-7. Variance analysis of seed yield per plant and its components in populations with removed 50% of plants at stages V-3, V-5 and V-8 of plant development in 1987, and at stages V-3 and V-6 in low and high densities in 1988

Variance source	d.f.*	Seed yield per plant	Seed yield per plant day	Seed number per plant	100 seed weight	Pod number per plant	Pod number branches stem	Pod number sterile	Seed number per pod
1987									
a	1	**	**	**	**	**	**	**	**
b	11	**	**	**	**	**	**	**	**
c	11	**	**	**	*	**	**	**	ns
d	36	**	**	**	ns	**	**	ns	*
e	2	**	**	*	*	*	ns	ns	ns
f	118	26.3	26.9	309.7	2.6	422.5	311.7	70.9	23.0	3.8
1988 - low density									
a	1	**	**	**	*	**	**	**	**	ns
b	5	**	**	**	**	**	**	**	**	**
c	5	ns	ns	ns	ns	ns	*	ns	**	ns
d	12	ns	ns	ns	ns	ns	ns	ns	ns	ns
e	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
f	23	3.3	25.1	16.9	2.6	28.7	4.6	11.2	7.4	5.5
1988 - high density									
a	1	**	**	**	*	**	**	**	**	**
b	5	**	*	**	**	**	**	**	**	**
c	5	ns	ns	**	ns	ns	ns	*	ns	ns
d	12	ns	ns	ns	ns	ns	ns	ns	**	ns
e	1	ns	ns	ns	ns	ns	ns	ns	ns	ns
f	23	8.5	58.8	54.1	5.0	8.2	3.0	1.9	1.9	4.2

Notes:
* degrees of freedom
a linear regression (treatment), tested against c or f
b genotypes, tested against c or f
c genotype x treatment interaction, tested against d
d pooled deviations, tested against f
e replications, tested against f
f error, mean square

Table VI-8. Stability parameters of seed yield per plant and its components in populations with removed 50% of plants at stages V-3, V-5 and V-8 of plant development in 1987, and at stages V-3 and V-6 in low and high densities in 1988

Genotype	Seed yield per plant	Seed yield per day	Seed number per plant	100 seed weight	Pod number per plant	Pod number per stem	Pod number sterile branches	Pod number	Seed number per pod
1987									
AR1	1.31	1.35	1.42	-1.14	1.58	1.43	1.92	1.39	3.01
IHA	0.92	1.02	0.67	-0.32	0.92	1.22	0.36	0.99	2.37
S23	1.20	1.31	1.48	0.57	1.39	1.39	1.40	1.29	0.09
R18	0.85	0.89	0.90	-0.50	1.01	0.86	1.38	0.67	0.20
POL	0.92	1.00	0.79	-0.97	1.01	0.94	1.19	1.07	-0.74
PRO	1.08	1.22	1.04	-0.39	0.95	0.87	0.94	1.29	0.10
Mean	1.05	1.13	1.05	-0.46	1.14	1.12	1.20	1.12	0.84
KHO	1.06	0.92	0.86	4.88	1.01	1.04	0.81	1.86	0.79
TOS	1.12	0.94	0.81	4.45	0.74	0.69	0.78	0.77	1.16
SHI	0.80	0.79	1.77	-0.67	1.25	1.19	1.39	0.93	0.20
KMI	1.09	0.91	0.95	3.65	0.82	0.75	0.81	1.39	0.55
OKU	0.89	0.89	0.50	0.54	0.63	0.70	0.58	0.23	0.84
WKO	0.77	0.77	0.82	1.89	0.70	0.93	0.42	0.12	3.44
Mean	0.96	0.87	0.95	2.46	0.86	0.88	0.80	0.88	1.16
LSD 5%	0.42	0.43	0.55	4.42	0.44	0.60	0.47	0.65	ns
1988 - low density									
AR1	1.21	1.19	1.34	-0.27	1.70	2.37	1.42	3.60	1.72
S23	0.61	0.68	0.77	1.82	0.83	0.20	1.03	1.12	-0.41
POL	1.10	1.24	1.19	2.22	0.88	0.28	0.90	1.03	-0.44
PRO	0.68	0.80	0.52	0.57	0.59	0.29	0.65	0.22	2.08
WKO	1.06	0.91	0.84	0.70	0.91	1.64	0.91	-0.32	2.47
SHI	1.33	1.18	1.33	0.96	1.09	1.23	1.08	0.36	0.58
LSD 5%	ns	ns	ns	ns	0.96	1.47	ns	2.21	ns
1988 - high density									
AR1	0.74	0.71	0.71	0.44	0.86	0.51	1.04	2.44	1.38
S23	0.80	0.90	0.93	0.57	1.02	1.06	0.97	1.57	0.92
POL	0.73	0.80	0.72	2.38	0.74	0.76	0.64	0.33	0.39
PRO	1.03	1.11	0.92	0.50	0.98	0.85	1.09	0.92	1.07
WKO	1.14	1.07	0.82	2.76	0.88	1.05	0.79	0.18	1.70
SHI	1.56	1.41	1.90	-0.65	1.52	1.78	1.49	0.56	0.54
LSD 5%	ns	ns	0.58	ns	ns	ns	0.44	ns	ns

when thinned in later stages (Fig. VI-6). The stability parameters of Polish genotypes varied and were above the average, and these of Japanese were similar to each other and below the average (Table VI-8).

Seed number per plant declined when thinned in later stages (Fig. VI-7). In 1987, 'Suzuhime', 'S23' and 'AR1' were above average sensitive to thinning stages (Table VI-8). In 1988, in the high density planting, 'Suzuhime' also was more sensitive to thinning stages than other genotypes. In 1987, 'Okuhara', 'IHAR-NK' and 'Polan' ('Polan' also in the high density in 1988) were relatively tolerant to thinning stages (Table VI-8).

In 1987, on the average in hundred seed weight, the Polish genotypes were more stable, in the response to the thinning stages than Japanese cultivars (Table VI-8). The Polish genotypes excluding 'S23' and Japanese cultivars excluding 'Suzuhime' showed reverse tendency (Table VI-8). For this reason means over all genotypes showed no trend (Fig. VI-8).

Pod number per plant and its fractions were decreasing when thinning was done in later stages (Fig. VI-9). In 1987, the stability parameters could diverse within group of Polish and Japanese genotypes, though the former tended to respond stronger to stages of thinning than the latter (Table VI-8). In 1988, in the low planting density, in pod number, 'AR1' showed high sensitivity to thinning stages. In the high density, 'Suzuhime was more responsive in pod number on

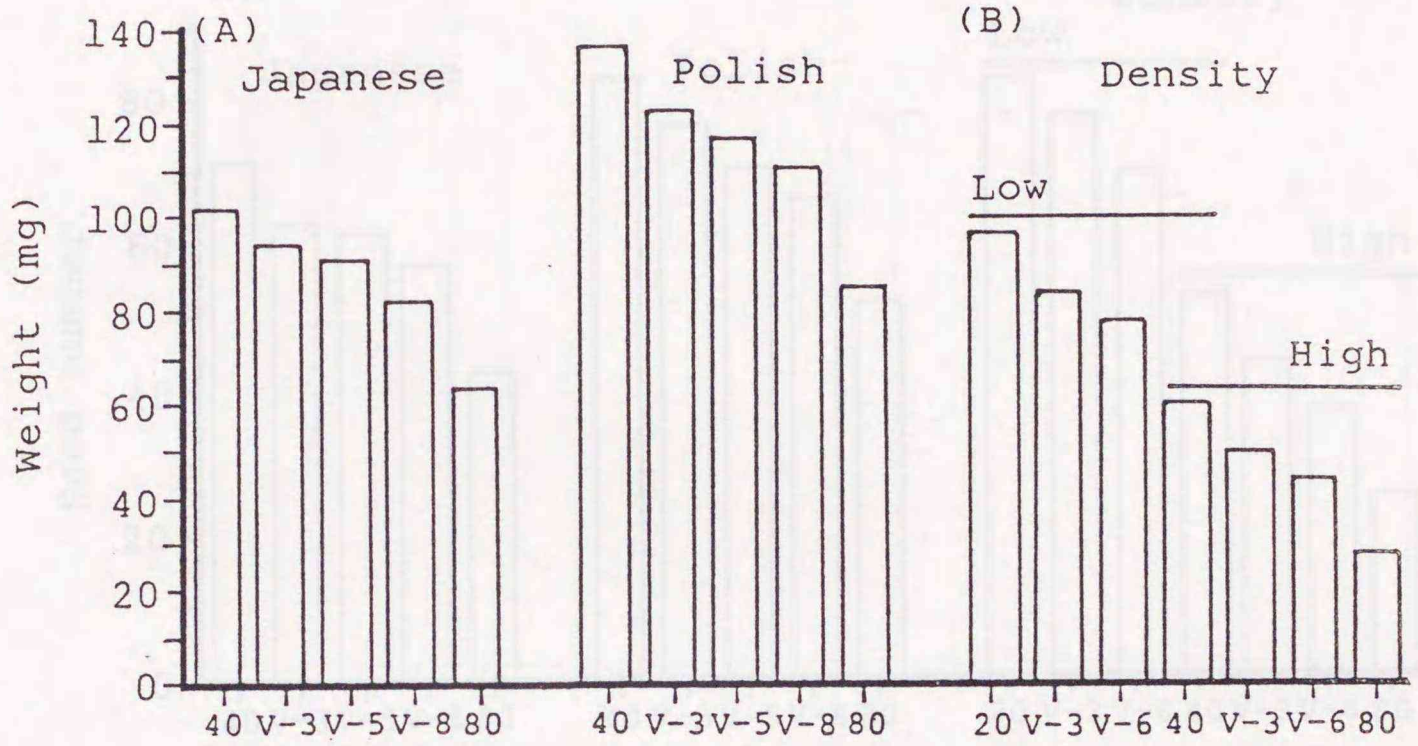


Fig. VI-6. Daily seed yield efficiency in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

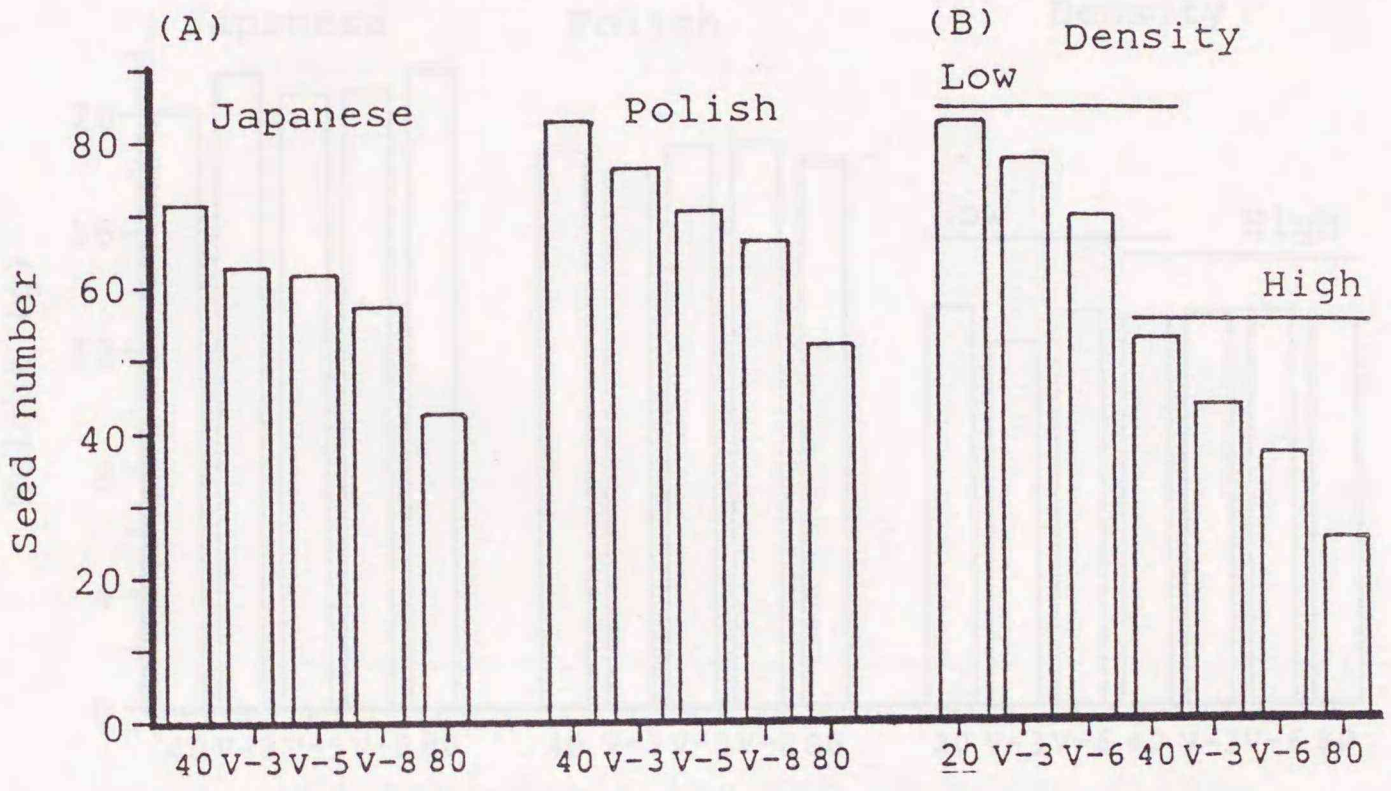


Fig. VI-7. Seed number per plant in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

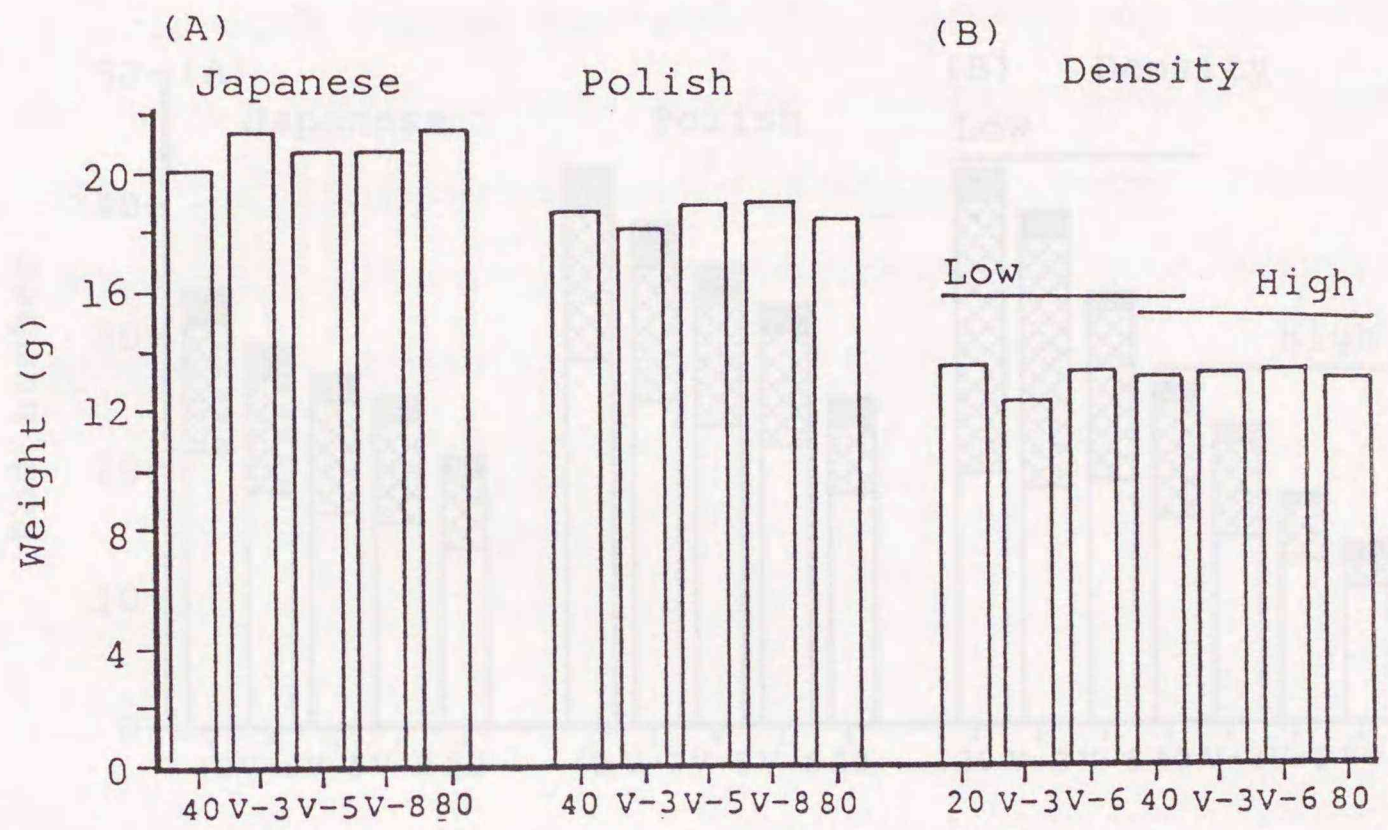


Fig. VI-8. Hundred seed weight in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

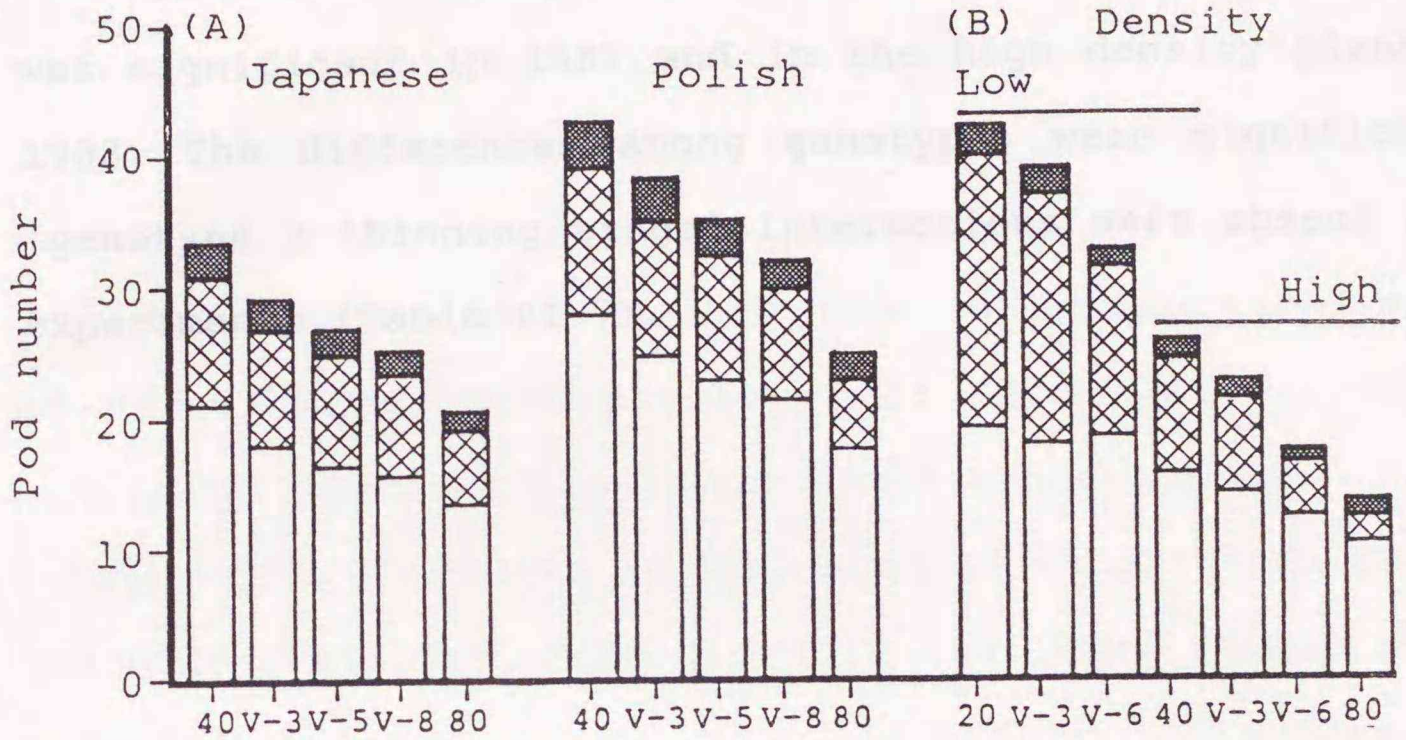


Fig. VI-9. Pod number per plant and its components in populations with removed 50% of plants (A) at developmental stages V-3, V-5 and V-8 of Polish and Japanese genotypes in 1987 and (B) at stages V-3 and V-6 in low and high densities over Polish and Japanese genotypes in 1988 (20, 40, 80 - control densities)

- Sterile - total
- On branches - fertile
- On stem - fertile

branches than other genotypes which were not much differentiated (Table VI-8).

In sterile pod number per plant, 'Wasekogane' was insensitive to thinning stages because of few sterile pods in every treatment (Table VI-8).

In seed number per pod the response to thinning stages was significant in 1987 and in the high density planting in 1988. The differences among genotypes were significant but 'genotype x thinning stage' interactions were absent in both experiments (Table VI-7).

4. Discussion

Super-early genotypes are habitually grown in the higher latitudes which impose long daylength and relatively harsh and short growing conditions. By nature their growth potential is relatively restricted in the time and space than that of early maturing genotypes. The super-early genotypes tend to produce more branches but their growth ceased earlier than growth of branches of early genotypes. Developing pattern like this imposes some restrictions on compensating abilities of super-early genotypes in their life history and space available. It means that super-early genotypes may lose their compensation abilities earlier than early maturing genotypes and cannot utilize space given in the later stages of plant development.

As it was presented in the previous chapters the interrow space had some effects, and the intrarow space had not any substantial impact on phenological characteristics. The thinning of fifty percent of stand at different stages of plant development failed to alter meaningfully phenological characteristics because it decreased plant density in the intrarow space and left the interrow space intact. Growing conditions in the field in 1988 were inadequate when compared with the field conditions in 1987. Circumstances like this possibly could impose some limitations on plant developmental processes, restrict the competition stress and, as a result, produce less apparent differentiation in the phenological and

other characteristics.

The obvious indicator of poorer growing conditions in 1988 was the lack of full canopy closure observed in the Polish and Japanese genotypes. It seems that less favorable growing conditions had substantial effect on expanding branches and leaves and prevented full canopy closure in the interrow space. Moreover, the competition stress was probably low and could contribute to the repression of the response of genotypes to thinning stages (Costa et al., 1980). However, some early ripening genotypes showed substantial reaction to additional space given at different stages of plant development. For example, the Japanese cultivars were more advanced in shadowing the interrow space than Polish genotypes which growth was more retarded. It seems that short stature, super-early genotypes need non-stress field conditions for proper growing.

When plants were left longer in the higher density, they competed for light as limited resource in mutually shadowing community and grew taller. The decreasing tendency in the branch number, biomass and stem diameter showed that filling and utilizing an additional space given in the later stages of plant development depended on genotype properties such as beginning and end of flowering and maturity. Early maturing genotypes seemed to have greater potential in compensating stand losses than super-early maturing genotypes which grow rapidly and were short in stature.

The increased lodging score which appeared when thinned

in the later stages proved that long competition in the dense population stress imposed in the early stages of plant development may be hazardous. Moreover, its effects were irreversible even when additional space was given later. The thinning stages affected more intensively the stem diameter of the Japanese cultivars than that of Polish genotypes. It seems that stem diameter depends heavily on genotype. The super-early genotypes suffered less from competition stress because they grew short and developed rather narrow profile stature due to upright branches. They could attain more rapidly to final thickness of stem diameter. Longer and bushy growing cultivars suffered more from competition stress which suppressed thickening of their stem diameter relatively more than super-early genotypes.

The thinning at late stages of plant development increased the height of basal pod set and reduced the number of pods set in the bottom parts of plant canopy because these characteristics are associated with the increase in the plant height which also occurred in the higher planting density of the previous chapter. In the basal pod height the Japanese cultivars were more responsive to different thinning stages than Polish genotypes. It was due to higher competition stress (less space and light available) in the Japanese cultivars with taller stature. However, the Polish genotypes were more responsive in the pod numbers in bottom parts of canopy. It was the result of their short and narrow profile canopies imposing the lesser stress and allowing to penetrate

more light into canopies.

Mature plant weight and its fractions decreased when thinning was done in the later stages. This indicated that additional space given after V-3 stage of plant development cannot be entirely utilized and the losses in the biomass cannot be fully compensated. The response to thinning stages was stronger in the branch than stem weight. It confirms findings of other workers who reported that soybean compensation abilities depends on the branch development and filling available space by them (Lehman and Lambert, 1960, Green et al., 1977, Stivers and Swearingin, 1980).

It was evident that on the average, seed yield could not be compensated fully when fifty percent of plants was removed at V-3 stage or later. However, the narrow leaflet, early cultivars 'Wasekogane' and 'Suzuhime' showed that the high compensation rate is possible and depends on genotype properties.

The time aspect of seed yielding is expressed in the daily seed yield efficiency. It was apparent that super-early genotypes with high daily seed efficiency were relatively more responsive to thinning stages than early genotypes. Relatively great but unstable daily seed efficiency combined with high harvest index showed that in the time aspect the super-early genotypes were highly competitive in utilizing available resources when compared with more late genotypes but were unable to utilize efficiently additional space given

after V-3 stage of plant development.

Hundred seed weight showed reverse tendency in the response to thinning stages in the super-early and early cultivars. Except the very small seeded cultivar 'Suzuhime' the other Japanese genotypes showed decreasing and except 'S23', the other small seeded Polish genotypes showed increasing tendency in the hundred seed weight when thinning was done in the later stages. This response can be associated with seed number per plant and per pod produced by super-early and early genotypes. Even though seed number per pod was rather independent from the thinning stages, the stability parameters of both genotypes ('S23' and 'Suzuhime' - above mentioned reverse response) had high and low stability parameters in the seed number per plant and per pod, respectively.

Looking at examined characteristics from the standpoint of super-early versus early genotypes it was evident that regarding particular genotypes some of their characteristics are completed earlier and other later in the life history and this imposes some limitation on the pattern of compensation abilities of soybean plants.

In general, it may be concluded that rapidly developing super-early genotypes were earlier loosing their ability to compensate plant losses when compared with more slowly and longer developing early cultivars.

VII. General discussion

Successful breeding and adapting the soybean cultivars into cool climate dates back about two decades and is associated with project devised and carried out in Sweden (Holmberg, 1973). In this program series of daylength tolerant cultivars was selected, with the most famous creation named 'Fiskeby V'. This super-early cultivar proved to be chilling and daylength tolerant and is extensively used in breeding for cool climates. It is a hybrid of genotypes originated from Tokachi Plain, Manchuria and northern Europe. After 1970, the breeding program for selecting soybean was initiated in Poland. Tested in present experiments Polish cultivars are first fruits of that work. Some of Polish breeding lines have 'Fiskeby V' as an ancestor. In Poland, starting from 1980 the area under soybean is increasing slowly but steadily.

As long as mechanical cultivation was a main means for keeping soybean crop weed free, and climatic conditions were mostly favorable, the wide interrow space planting could not be questioned. Along with progress of crop management in its broad meaning, soybean production expanded to zones where narrow interrow space was more suitable for maximizing seed yields. Soybean cultivars primarily were selected for growing in the wide interrow space. Switching to narrow interrow

planting impose a question of 'cultivar x plant density' interaction. To answer it a conspicuous number of research was carried out. Many of the reports found early, short season genotypes to be more responsive to narrowing interrow space than late, full season genotypes. Generally, it is already well established that in narrow interrow space combined with increased population density plants grow taller, elongate internodes and set basal pod higher. Such planting reduces branch, pod and seed number per plant. The response of agronomic characteristics of particular genotypes to population density remains to be established. Considering seed yield, some conflicting data were reported. Nevertheless, in most of such cases the absence of yield advantage in narrow row planting patterns has usually been reported from southern soybean producing states (Johnson, 1976) or when soybean genotypes were tested in yield limiting environment (Doss and Thurlow, 1974; Hoggard et al., 1978; Taylor, 1980; Alessi and Power, 1982; Reicosky et al., 1982; Cooper and Jeffers, 1984).

Some of associations between planting density and characteristics already found application in the practice. In soybean management, especially in northernmost zone of soybean cultivation the height of the lowest pod and distribution of pods along canopy, particularly bottom parts of plant height, are crucial when harvest is done by combine. Cutting bar on uneven fields cannot float entirely on the soil surface and may cause considerable harvesting losses. In solving

this problem, the impact of planting density on the height of basal pod can be utilized. For particular cultivars and environmental conditions adjusting proper planting density can shift bottom pods higher on stature and meet requirements of machinery used for harvesting.

The present work proved that Polish cultivars were super-early maturing in Hokkaido environment. Moreover, when planted in dense populations arranged in narrow interrow space they may produce comparable yield to native to Hokkaido early cultivars. In some circumstances super-early genotypes seemed to be alternative to early maturing genotypes.

Super-early genotypes may find application in devising crop rotation systems with winter small grains and other crops. In agricultural practice wheat (Triticum aestivum L.) plays major role. In northern Europe rye (Secale cereale L.) is a staple, and rapeseed (Brassica napus L.) is significant in oil production. As the winter crops, to overwinter safely they must be planted early in the autumn and attain proper stage of development before frosts occur. Thus, proper time of planting is crucial for obtaining optimal yields. In the rotation, above mentioned crops may follow super-early soybean because it is ready for harvesting in the beginning of September. Such early harvest leaves enough time for preparing seedbeds and planting winter crops in proper period. Conventional cultivars ripen late and this makes impossible to plant following them winter crops in the best phenological time. Moreover, small grains following soybean may benefit

from nitrogen left with plant residues reach in this element. This may contribute to significant lowering the costs of small grain production.

Other application of super-early genotypes may be found in double cropping systems (producing two crops in one year on the same field) which are spreading out from long season areas. Some advantages of a double crop system include: I - the ability to produce two crops in one season, II - a decrease in tillage requirements compared to conventional single crop soybeans, III - reduction of soil loss, and IV - the ability to produce yields comparable to soybeans in a single crop system (Panter and Allen, 1989). Double cropping with soybean has increased in the southern United States. This cropping system gives farmers the opportunity to increase profits through increased productivity from their land (Dabney et al., 1988; Hairston et al., 1987; Raymer and Bernard, 1988a and b). NeSmith et al. (1987) reported that in Georgia (southern USA) approximately 40% of the soybean hectarage is double cropped. The planting of soybean following harvest of a previous crop has proven effective under the longer growing season. In recent years, double cropped hectarage has increased in the southern Midwest, USA. Currently 40°N latitude represents the northern limit for producing economical returns from double cropping soybean. In higher latitudes increasing area of double cropped cultivation requires very early maturing, viz. super-early genotypes.

Considering valuable protein and oil extracted from

soybean it may have role in replacing animal fat and protein in human diet on vast areas of land. Cultivation of super-early genotypes may contribute to expand the area of soybean cultivation and produce healthy and cheap food.

VIII. Summary

It was expected that super-early soybean genotypes may be alternative or supplementary to native cultivars in Hokkaido conditions. Introduction of a new germplasm requires revision and adjustments in crop management. The ecological features of super-early genotypes of soybean need to be elucidated. Space filling and compensation abilities of super-early genotypes may differ from cultivars grown in Hokkaido. For this reason the response of super-early genotypes to plant density altered by interrow and intrarow space was the crucial problem of this work. Also the response of super-early genotypes to additional space given by means of thinning in different stages of plant development remained to be clarified.

In this study some attempts were made to examine the behavior of super-early genotypes improved, selected and released in Poland when compared with Japanese cultivars in Hokkaido (Sapporo) conditions. The study was concentrated on phenological, morphological, biomass and seed yield characteristics.

The Polish genotypes were different regarding most characteristics from early or extremely early Hokkaido cultivars. The former began to flower and matured earlier than the latter and then were defined by the super-early maturity genotypes. Tests proved that super-early genotypes did not react to Sapporo conditions. On the other hand, the Hokkaido

cultivars delayed harvesting maturity in Polish conditions.

The super-early genotypes and early cultivars represent two distinctive plant types. Super-early genotypes are typical long daylength morphotypes and include determinate, semideterminate and indeterminate growth habit. They develop rather short, narrow profile stature and need more time to attain canopy closure than early cultivars which grow vigorously. This predisposes them to cultivation in dense planting with both interrow and intrarow space reduced. Extremely early or early Japanese cultivars represent relatively short daylength morphotype. They carry determinate or semideterminate growth habit and produce biomass abundantly. This predisposes them to more spacious planting.

Strong point of super-early genotypes was their high rate of seed yield efficiency per day during vegetation period. Sufficient seed yield per plant and earlier harvest maturity of super-early genotypes caused substantial increase in their seed yield efficiency per day when compared with early genotypes. The other advantage of super-early genotypes was their apparent harvest index substantially higher than that of early or extremely early cultivars. It seems that super-early genotypes allocated relatively more dry matter to seeds.

Super-early genotypes produced slender stem and due to that, were not resistant to lodging, though in dense conditions their lodging did not increase as early cultivars did.

The short stature of super-early genotypes was associat-

ed with pods distributed heavily in the bottom parts of canopy and low height of basal pod especially. But their pods could be set higher if cultivated in the more dense planting. This may allow to avoid the hazard of increased harvest losses. Adjusting proper planting density for super-early genotypes seems to be important problem under particular environment.

It was found that super-early genotypes compensated less to the space given in different stages of plant development. Their weak compensation of seed yield, daily seed yield efficiency, and seed number were apparent when thinned at the later stages of development. In general terms, the super-early genotypes finished their vegetative growth earlier and were less able to compensate plant losses and to fill the space given in the late stages of plant development.

Present study proved that super-early genotypes of soybean could contribute to spreading cultivation of that valuable crop to areas with seed yield limiting factors and find some application in agricultural practice of Hokkaido conditions.

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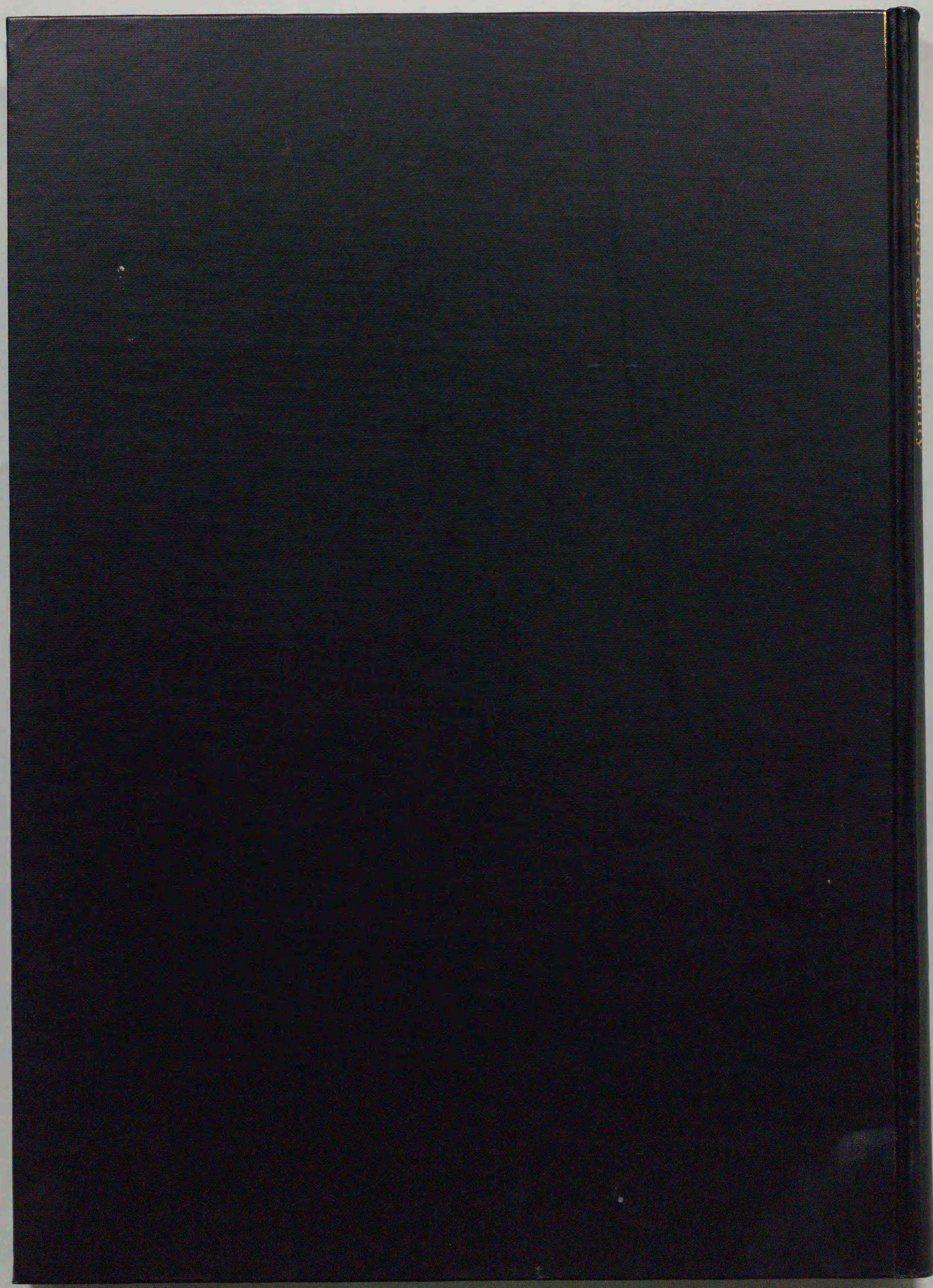
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inches 1 2 3 4 5 6 7 8

cm 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

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A 1 2 3 4 5 6 **M** 8 9 10 11 12 13 14 15 **B** 17 18 19