Investigation of some production factors on yield and quality of dry beans

Nemeskéri, E.

Agrona Ltd, 4002 Debrecen, Domokos Márton kert 72/B

Summary: The correlation between plant density and yield average shows that the volume of yield increases in varieties of large and medium-size seeds up to a plant density of 285–400 thousand/ha, after which it declines.
On the basis of the results, yield averages at plant densities of 285–334 thousand plant/ha are 0.17 t/ha higher than those achieved at low density (200 thousand plant/ha).
High levels of potassium fertilizer did not enhance the yield of dry beans. With adequate-water supply the high level of potassium decreased the number of pods and seeds per plant compared with a basic level of fertilizer, which could ensure 2.5 t/ha yield.

Key words: dry beans, yield-quantity & quality, plant density, potassium fertilizer, K–Mg–Ca-relationships

Introduction

Legumes of large seed size such as peas, beans and soybeans are more sensitive to mechanical damages than cereals. The quantity of abnormal seedlings increase due to the invisible breaks and cracks of cotyledons resulting from the strokes of the threshing drum *(Szabó* 1980). The ratio of abnormal seeds increased when there was a long dry period during seed development *(Nemeskéri* 1995, *Vieira* et al. 1992) and in seeds stored at high temperature, respectively *(Hernandez-Livera* et al. 1990).

Not only the high temperature but also bacterial diseases caused by *Pseudomonas phaseolicola* and *Xanthomonas phaseoli* decreased seed yield as well. Due to *Xanthomonas phaseoli* infection the leaves became brown and dry, consequently the leaf area and photosynthesis decreased. In the case of serious bacterial infection the rate of aborted seeds increased inside the pods, thereby seed yield decreased significantly. A negative correlation has been found between seed size and the yield of bean cultivars. Some genetic factors related to large seed size were responsible for relatively low yield ing capability in varieties of large seeds *(Clark & Peck* 1968, *Sangakkara* 1989, *Sexton* at al 1994). Studying the factors affecting growth and crop development, others *(White & Gonzales* 1990) stated that the size of the seed is correlated with the size of the stomatal closing cells, the parenchyma of cotyledons, endoderm of hypocotyle and root.

The type of bushes and the stability of stems in varieties cultivated in the field limited plant density. Various seeding norms are needed for different seed sizes to ensure optimal plant density. The use of large seeding rate over the optimum increased the cost of production particularly in the case of beans of large seeds.

Potassium was said to enhance yielding capacity, resistance to stresses and diseases and improve the quality of crops. *Bergmann* (1979) published that potassium fertilizer increased or decreased the yield depending on the ratio of K/Mg in the soil. When this ratio was near 1, the yield increased but over 3 it caused decreasing yields. High potassium content in the soil resulted in Mg and Ca deficiency of the plants thereby their cooking quality might decline.

In this study, the optimal plant density of dry bean varieties various seed size were investigated. We tried to reveal the correlation between plant density and thousand seed mass and seed quality, respectively. The latter was related with some degree of resistance to bacterial diseases and breaking.

We have analyzed the effects of potassium on yield, bacterial rate of diseases and the nutritive quality of seed (seed coat, protein content) in bean varieties.

Material and method

Experiment I

Between 1997 and 1999 investigations were made to determine the effect of planting density on in three dry bean cultivars representing small, medium and large seed size groups. The field experiments had four replications in "split-plot" arrangements on chernoziem soil. Sowing was carried out with Wintersteiger seeding-machines. The distance between rows was 50 cm and the length 9 m and so the size. The group with low thousand seed mass (200g.) included the white, round-seed of plot was 13.5 cm^2 *Debreceni gyöngy* variety. This variety grows to an erect bush with small leaves. *Békési fehér* bean variety represented the white medium seed size group (300g), it had a strong stem with large leaves. The large-seed group (500 g) included the *Debreceni tarka* bush bean variety, which grows to an erect stem with large leaves. Its kidney-shape seeds are colored with vine-red spots on light cream background like quaileggs. Six different plant densities were chosen based on theoretical seeding norms as treatment taking the percent of germination seeds into consideration.

Every year, the experiments were planted between 5 and 12 of May and harvested by plot-machines until 20th, August depending on the weather. The harvest started at 16 percent of moisture content of seeds except in 1999 when it was made at 18 percent. The samples were gathered from each of the replicated plots to determine the thousand seed mass, the ratio of diseased seeds and broken seeds. The ratio of infected seeds and broken seeds was expressed in percent of weight.

Data were evaluated for two factors by the ANOVA statistical method *(Sváb* 1981) and by regression analysis. The quality of seed was characterized by the ratio of diseased seeds and broken seeds since these affected the amount of abnormal and diseased seedlings indirectly.

Experiment II

In 1999 and 2000 the experiments were carried out to investigate the utilization of potassium fertilizer of small and large seed-size bean varieties such as *Debreceni gyöngy* and *Debreceni tarka* grown on chernoziem soil. This soil was rich in humus, well supplied with nitrogen and phosphorus and satisfactory in potassium. The size of plots and the arrangements were the same as described in Experiment I.

Fertilizer treatments were as follows:

∅ treatment means the control where the plants were grown without fertilizer

$K_{1.0}$ *means the basic treatment* (N: P_2O_5: K_2O = 1: 0.5: 1) where the demand of potassium fertilizer was itended to produce 2.5 t/ha yield. This way the fertilizer needed was based on soil analysis, i.e. N: 90, P_2O_5: 30, K_2O: 100 kg/ha.

$K_{1.5}$ *treatment* where the potassium fertilizer was increased to 1.5-fold of the basic treatment and $K_{2.0}$ *treatment* where it was increased to 2.0-fold. The nitrogen and phosphorus doses were constant in all fertilizer treatments.

We gathered 10–10 plant samples from the four repetitions, and counted the number of pods and seeds, the amount of diseased seeds and measured the thousand seed mass. The ratio of seed mass and seed coat mass was expressed in seed-coat %. The measurement of seed protein was made with the Kjel-Foss method in the Central Laboratory of the Agricultural University of Debrecen. The results have been evaluated using ANOVA statistical methods.

Results

Experiment I

In all the three years the flowering time of plants were at the same periods between 15 and 20 of June. In 1998 and 1999, temperature and precipitation were favorable on seed development. There were no differences in yield and bacterial infection between white, small and medium seed-size bean varieties (*Table 1)* The average annual yield

Table 1 Major production traits of beansbean varieties averaged over the different plant density treatments

Trait	Variety	1997	1998	1999	Averaged over years
Plant height (cm)	Debreceni gyöngy	55.68 b	50.67 b	58.29 b	***54.88***
	Békési fehér	65.26 a	53.88 a	63.38 a	***60.84***
	Debreceni tarka	63.08 a	47.06 c	59.63 b	***56.59***
	LSD5%	*3.00*	*2.55*	*2.22*	
	LSD1%		*2.80*	*3.35*	
Yield (t/ha)	Debreceni gyöngy	2.89 a	2.58 a	2.21 b	***2.53***
	Békési fehér	2.31 b	2.56 a	2.56 a	***2.48***
	Debreceni tarka	1.67 c	1.12 b	1.48 c	***1.42***
	LSD5%	*0.13*	*0.2*	*0.31*	
Thousand seed mass (g)	Debreceni gyöngy	221.30	181.67	162.00	***188.30***
	Békési fehér	320.80	312.38	315.08	***316.09***
	Debreceni tarka	511.40	510.42	501.00	***507.61***
	LSD5%	*20.80*	*4.95*	*12.88*	
Bacterial seed infection (%)	Debreceni gyöngy	7.06 b	8.37 b	2.97 b	***6.13***
	Békési fehér	6.19 c	9.22 b	3.46 b	***6.29***
	Debreceni tarka	11.42 a	22.43 a	13.51 a	***15.79***
	LSD5%	*3.43*	*2.05*	*0.50*	
Broken seeds (%)	Debreceni gyöngy	3.83 b	7.58 c	0.22 c	***3.88***
	Békési fehér	15.43 a	10.96 b	1,27 b	***9.22***
	Debreceni tarka	17.07 a	19.2 a	3.70 a	***13.32***
	LSD5%	*2.50*	*1.34*	*0.66*	

• Different letters within the columns indicate significant differences between the data pairs.

showed that the yield of the small seed variety was more stable than that of the medium seed size variety. The *Debreceni tarka* with large seed yielded 50% less than the others, which was contributed not only to its genetic background but its susceptibility to *Xanthomonas phaseoli* as well. Lots of factors such as the moisture content and size of the seed, the close joints of cotyledons and the structure of the seed coat influences the mechanical damages on seeds. The large-seed variety was the most sensitive to mechanical damages as its ratio of broken seeds was the highest (17–18%). This tendency could also be attributed to the high moisture content of seed at harvest (18%).

Table 2 shows the changes of production traits in bean cultivars grown at different plant densities. The treatment of 200 thousand plant/hectare was considered to be the control and an equivalent of rare plant density in seed production. According to the results, increasing plant density enhanced the yield. In the average of years the yields were 0.17 t/ha higher at plant densities of 285–334 thousand plants/hectare than those achieved at low density (200 thousand plants/ha). Over the 285–334 thousand plant density yield dropped to the half (0.08 t/ha). It is known that genes determine thousand seed mass, however, it changed slightly depending on years. The higher plant density slightly decreased the

Table 2 Effect of plant density/ha on the production traits of bean varieties with different seed size

Trait	Plant density thousand/ha (2)	1997	1998	1999	Averaged over years
Plant height (cm)	200	59.31 b	51.71	57.33 d	***56.12***
	250		51.00	58.17 cd	***54.59***
	285	61.76 a	49.46	60.33 bc	***57.18***
	334		51.29	61.25 b	***56.27***
	400	62.95 a	50.17	60.83 b	***57.98***
	450		49.58	64.67 a	***57.13***
	LSD5%	*1.94*		*2.57*	
Seed yield (t/ha)	200	2.16	1.93 b	1.88 b	***1.99***
	250		2.00 ab	1.94 b	***1.97***
	285	2.27	2.07 ab	2.10 ab	***2.15***
	334		2.16 a	2.13 a	***2.15***
	400	2.34	2.18 a	2.18 a	***2.23***
	450		2.19 a	2.26 a	***2.23***
	LSD1%		–	*0.19*	
	LSD10%		*0.21*		
Thousand seed mass (g)	200	363.48	340.75 a	329.58	***344.60***
	250		337.75 a	328.08	***332.92***
	285	348.14	335.08 a	328.33	***337.18***
	334		333.42 a	325.58	***329.50***
	400	341.90	335.25 a	321.66	***332.94***
	450		326.67 b	322.92	***324.80***
	LSD10%		*7.71*		
Bacterial seed infection (%)	200	8.88	12.21	6.58	***9.22***
	250		12.61	6.71	***9.66***
	285	8.66	13.57	6.47	***9.57***
	334		13.92	7.07	***10.50***
	400	7.13	14.71	6.32	***9.39***
	450		13.03	6.72	***9.88***
Broken seed (%)	200	12.31	11.54 b	1.74	***8.53***
	250		11.99 b	1.80	***6.90***
	285	12.08	14.45 a	1.82	***9.45***
	334		13.39 a	1.80	***7.60***
	400	11.91	12.80 ab	1.67	***8.79***
	450		11.32 b	1.56	***6.44***
	LSD5%		*2.03*		

• Different letters within the columns indicate significant differences between the data pairs.

thousand seed mass but significant differences were only detected in 1998. The higher plant density had no significant effect on the ratio of diseased seeds, however this ratio slightly increased at high plant density (400–450 thousand plants/ha) particularly in bean varieties, which have been susceptible to bacterial diseases. The results concerning the degree of broken seeds were contradictory. Their ratio was the highest at plant densities of 285–334 thousand plant/ha but it was slightly lower at high plant density.

Seeding norms and surpluses for bean varieties with different seed size based on theoretical seeding norms could be seen on *Table 3*. Return's index means the ratio of yield surplus due to increased plant density divided by the surplus of the seed planted. According to the return's index the used densities of 285–334 thousand plant/hectare were the most economical for producing beans of medium and large seeds. Others *(Unk* 1984, *Velich & Unk* 1995) found that 300–440 thousand plant/hectare was satisfactory for seed production of dry and French bean cultivars. The largest return's index was obtained by using optimal seed norms of good seed quality (160–170 kg/ha) which is equivalent to 285–334 thousand plant/ha densities in bean varieties of large-seed. Under the present experimental soil and environmental conditions the plant densities of 285–334 thousand plant/hectare, which coincided with 110–120 kg/ha seeding norms, were the most advantageous in production of varieties with medium seed size.

We investigated the relationship between plant density and plant height, as well as the yield, thousand seed mass and ratio of diseased and broken seeds in varieties of different seed size. Analyzing all data, there was a mediocre correlation (r= 0.55) between plant density and yield only in *Békési fehér* bean variety representing the 300 g thousand seed mass group (*Figure 1*).The yield of this variety increased to the same extent from 285 to 400 thousand plants/ha based on Y' regression equation. The thousand seed mass of this variety did not change at high plant density. There was no correlation between plant density and yield in

Table 3 Seed norms and surpluses for bean varieties with different seed size

Plant density	Seed norm	Seed surplus	Yield surplus kg/ha		Averaged over years	Returns index *	Variety Thousand seed mass
Thousand/ha	kg/ha	kg/ha	1998	1999			
200–250	45–57	11	20	–30	–5	*–0.45*	Debreceni gyöngy
285–334	65–78	13	40	110	75	*5.77*	(Th.s.m. 200 g)
400–450	91–102	11	150	60	105	*9.55*	
200–250	68–85	17	130	180	155	*9.12*	Békési fehér
285–334	97–114	17	120	240	180	*10.59*	(Th.s.m. 300 g.)
400–450	136–153	17	-60	150	45	*2.65*	
200–250	114–142	28	80	20	50	*1.79*	Debreceni tarka
285–334	162–190	28	170	-60	55	*1.96*	(Th.s.m. .500g)
400–450	227–256	29	–70	30	–20	*–0.69*	

* Returns index = yield surplus/seed surplus

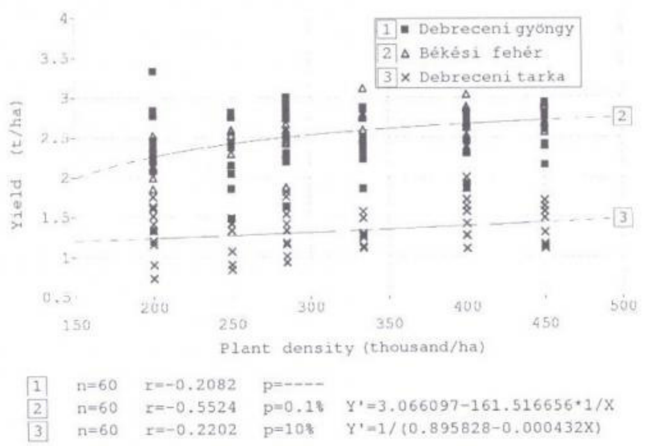

Figure 1 Effect of plant density on the yield of dry bean varieties with different seed sizes
Y: yield [t/ha] X: plant density [thousand/hectare]

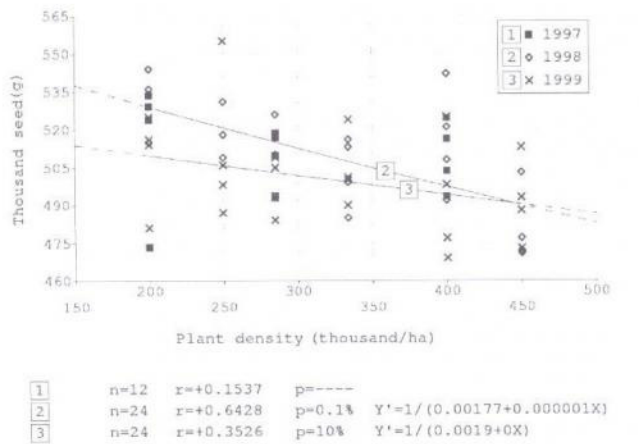

Figure 2 Effect of plant density on the thousand seed mass of dry bean variety Debreceni tarka
Y: Thousand seed mass [g.] X: Plant density [thousand/hectare]

small seed size (200 g) *Debreceni gyöngy* variety (*Figure 1*). Low correlation (r=0.22) could be shown between the plant density and yield of *Debreceni tarka* variety having 500 g thousand seed mass. The yield increased slightly as calculated on Y' regression equation from 285 to 400 thousand plants/ha, then it decreased. The low correlation coefficient (r=0.22) proved that the yielding capacity of large seed varieties hardly increased with enhanced plant density (*Figure 1*). At high plant densities, the plant height of *Debreceni tarka* variety increased but its thousand seed mass decreased significantly (*Figure 2*). It means that large-seed varieties grown over 334 thousand plants/ha densities decreased their thousand seed mass even under favorable climatic conditions.

Experiment II

In 1999, temperature and precipitation were favourable on pod set and seed development contrasted with the year of 2000, which was too dry. These different years demonstrated the effects of increased potassium fertilizer on the yield and seed quality well in beans grown at their optimal plant density. According to the results, potassium did not enhance bean yields. *Debreceni gyöngy* variety seemed to use the large levels of potassium for seed development better than the *Debreceni tarka* variety of large seed (*Table 4*). Pod number per plant in treatments compared with the control group were considerably higher due to the effect of the higher level of potassium. Significant differences among the fertilizer treatments could only be revealed in pod number/plant of small seed size beans. The large doses of potassium ($K_{2.0}$) being equivalent to 200 kg/ha decreased the pod number/plants and seed number/plant of small-seed beans, in contrast with beans of large seeds, where significant differences could not be detected. As a result of large potassium doses, flowering time was delayed and lots of pods were set but only a few of them became mature. This explained the decrease in the harvested number of pods and seeds.

Potassium is said to have a positive effect on resistance to diseases and the quality of crops. In the case of beans, the large doses of potassium applied decreased the amount of infected seeds but significant differences could only be revealed in *Debreceni gyöngy* variety with small seeds (*Table 5*). Some traits, such as color and thousand seed mass have influenced the attractiveness, and the others as the seed coat and protein content acted on food quality. There were no significant differences in seed coat and protein content between treatments (*Table 5*). In a dry year (2000), higher protein content was measured than in 1999. The differences in the protein content of both varieties were only significant between the control dose and moderately large potassium ($K_{1.5}$) doses. This means that moderately large potassium level is advantageous for food quality particularly in drought.

Conclusion

Seed size and the usage value of seeds, as well as maturity and bush types have determined the optimum plant density of bean varieties. The higher plant densities caused changes in yielding capacity, thousand seed mass and susceptibility to *Xanthomonas phaseoli* in different ways depending on the varieties of various seed sizes. The enhancement of plant number/hectare up to 400–450 thousand plant/ha did not effect yield and thousand seed mass in small-seed bean varieties. These varieties, like *Debreceni gyöngy*, could take up the fertilizer and water from decreased growing areas satisfactorily as a result of their slightly longer flowering periods, small leaves and erect bush type. We considered that these are indifferent to the decrease of growing areas, i.e. higher plant density. Varieties with determinate bush types and large leaves have larger nutrient and water requirements than that of bush

Table 4 Influence of potassium on yield capacity of dry bean varieties

Variety	Treatments	Seed t/ha			Pod/plant			Seed/plant		
		1999	2000	Averaged over years	1999	2000	Averaged over years	1999	2000	Averaged over years
Debreceni gyöngy	control Ø	2.39	1.81	**2.10**	20.95 c	14.00	**17.48**	61.20 c	23.00	**42.10**
	K1.0	2.02	2.32	**2.17**	31.40 a	12.80	**22.10**	105.80 a	22.30	**64.05**
	K1.5	2.22	2.23	**2.23**	31.70 a	13.80	**22.75**	95.60ab	18.00	**56.80**
	K2.0	2.43	2.30	**2.37**	27.20 b	15.40	**21.30**	87.60 b	23.60	**55.60**
Debreceni tarka	control Ø	0.94	0.63	**0.79**	6.13 e	4.90	**5.52**	15.00 d	7.90	**11.45**
	K1.0	1.31	0.84	**1.08**	8.65 d	7.40	**8.03**	22.90 d	10.50	**16.70**
	K1.5	1.22	0.90	**1.06**	9.38 d	8.20	**8.79**	20.50 d	10.50	**15.50**
	K2.0	1.15	0.63	**0.89**	7.58 ed	4.20	**5.89**	18.70 d	5.20	**11.35**
LSD 5%		0.38	0.50		2.50	7.90		12.90	12.10	
Differences of treatments LSD5%	0.53	0.71		**3.50**	11.20		**18.20**	17.10		

• Different letters within the columns indicate significant differences between the data pairs.

Table 5 Influence of potassium on yield quality of dry bean varieties

Variety	Treatments	Infected seed piece/plant		Averaged over years	Seed coat %		Averaged over years	Protein %		Averaged over years
		1999	2000		1999	2000		1999	2000	
Debreceni gyöngy	control ∅	15.5 b	20.4	**17.95**	8.79	8.00	***8.40***	19.43 b	21.86 b	**20.56**
	$K_{1.0}$	28.5 a	10.4	**19.45**	9.76	9.45	**9.62**	20.53 ab	23.0 ab	**21.77**
	$K_{1.5}$	21.1 a	10.7	**15.90**	11.13	9.14	**10.14**	21.82 a	25.48 a	**23.65**
	$K_{2.0}$	9.2 c	13.6	**11.40**	10.00	7.17	**8.59**	21.09 ab	25.05 a	**23.07**
Debreceni tarka	control ∅	3.6 **d**	6.0	**4.80**	10.54	10.58	**10.56**	19.97 b	22.73 b	**21.35**
	$K_{1.0}$	5.2 cd	7.3	**6.25**	10.73	9.58	**10.16**	20.86 ab	23.23 ab	**22.05**
	$K_{1.5}$	6.8 cd	9.5	**8.15**	11.39	9.05	**10.22**	21.49 a	25.11 a	**23.30**
	$K_{2.0}$	5.4 cd	4.5	**4.95**	10.69	9.95	**10.32**	21.36 ab	24.61 ab	**22.99**
LSD 5%		4.2	7.1		–	1.38		1.39	1.94	
Differences of treatments LSD 5%			10.0			1.95			2.74	

• Different letters within the columns indicate significant differences between the data pairs.

beans with small leaves. As plant density was increased, growing area was decreased therefore the utilization of nutrient and water might be disturbed. The use of optimum plant density in the production of large-seed beans is very important. Thousand seed mass decreased in the *Debreceni tarka* variety in the case of optimal plant density (334 thousand plant/ha) even under favorable climatic conditions. The plant height of varieties with large leaves increased slightly due to high plant density. These varieties need to have good stem stability because sprawling plants yield more diseased seed, thus lower seed quality. Comparing the optimal plant density of varieties, the ratio of broken seeds decreased at high plant density. Climatic conditions at large plant density seemed to be favorable to maintain the moisture of seeds, which resulted in the lower ratio of broken seeds. The varieties susceptible to *Xanthomonas phaseoli* produce higher ratio of diseased seeds depending on years, however, this ratio did not increase significantly with the enhancement of plant density. This was found in the case of *Debreceni tarka* and *Békési fehér* bean varieties. The seed quality of these varieties is controlled rather by genetic factors and not by plant density.

There were differences in the utilization of potassium in both bean varieties. The large doses of potassium fertilizer ($K_{2.0}$ =200 kg/ha) resulted in the decrease of the number of pods and seeds in small-seed *Debreceni gyöngy* bean because of its prolonged ripening. High potassium doses decreased the amount of diseased seeds in this variety. The differences in protein content were demonstrated between the control dose and moderately large potassium doses, which was advantageous for food quality in drought. There were no significant differences in resistance and other quality factors in the large seed *Debreceni tarka* variety susceptible to bacterial diseases. According to the results, the *Debreceni gyöngy* variety with small seeds and leaves could utilize the high levels of the potassium better than *Debreceni tarka* variety of large seeds and leaves.

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