Heat Tolerance in Grain Legumes

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Hitzetoleranz bei Körnerleguminosen

1. Introduction

The advancement of global warming increases the yield damages of grain legumes whose degree has been determined by genetic background, the nutriment and water utilisation of varieties. The beginning and final stages in development of plants are important for the yield quantity and quality. Most reproductive stages in common bean are sensitive to high temperatures, including flower bud formation, flowering, pollen formation and function, fertilisation, and pod and seed set (KONSENS et al., 1991; WEAVER et al., 1985). The heat shock caused male sterility under microsporogenesis of bean and cowpea plants, which is due to unviable pollens and anthers indehiscence. At the stage of flower buds heat shock prohibits the penetration of pollen tube into the stigma thus the number of pods decreases (GROSS and KIEGEL, 1994; WARRAG and HALL, 1983). In particular, high night temperature is very detrimental to pod and seed set in legumes including common bean (NEMESKÉRI et al., 1994), lima bean (*Phaseolus lunatus* L.) (FISHER and WEAVER, 1974) and cowpea (*Vigna unguiculata* (L.) (HALL, 1990). Drought during reproductive development of soybean has a significant effect on germination of harvested seed, and irrigation can overcome this effect. Thus full-reproductive-period irrigation in soybean grown in dry years will ensure the highest seed yield and that seed will have a high percentage of germination (HEATHERLY, 1993). During the reproductive period drought increases the ratio of shrivelled seed in early ripening soybean to a higher extent than in the middle-early ripening ones (NEMESKÉRI, 1994). High temperatures (32/28 °C day/night) during seed filling reduce the germination of seeds from well-watered plants grown in growth chambers (KEIGLEY and MULLEN, 1986). According to others (DORNBOS et al., 1989; SMICIKLAS et al., 1992) at the daytime greenhouse temperatures of 20 and 26 °C, the seed yield reductions and the drought stress effect on germination is small. VIEIRA et al. (1991) found no effect on germination but YAKLICH (1984) reported decreases in soybean seed vigour following drought stress during the seed-filling period. Peas are sensitive to water stress at the beginning of reproductive periods. FOUGEREUX et al. (1997) found that the water stress during the seed filling period in

Zusammenfassung

In dieser Arbeit wurde der Effekt hoher Keimtemperaturen auf die Saatqualität von Sojabohnensorten und Bohnengenotypen unter bewässerten und nicht bewässerten, trockenen Standortbedingungen untersucht. Nach vier bzw. acht Tagen wurde der Grad an Trockentoleranz durch den Anteil an abnormen oder kranken Keimlingen bestimmt. Die hohe Temperatur steigerte signifikant die Zahl an abnormen Keimlingen, welche von beiden Arten unter nicht bewässerten, trockenen Standortbedingungen stammten. Die chemische Zusammensetzung und die Wurzelentwicklung von Bohnen-, Sojabohnen- und Erbsenkeimlingen, die unter Standortbedingungen ohne Bewässerung wuchsen, wurden untersucht bei 20/10 °C (Tag/Nacht) als Kontrollgruppe sowie bei 25/25 °C (Tag/Nacht) und 30/30 °C (Tag/Nacht). Ein moderater Hitzestress (25/25 °C) verursachte einen ansehnlichen Rückgang der Wurzellänge von Keimlingen großsamiger Bohnengenotypen, nicht aber bei Sojabohnensorten. Temperaturerhöhungen veränderten die Eiweißgehalte der Schösslinge bei keiner Art, aber sie steigerten den Trockenmassegehalt signifikant, außer bei Erbsen. Bei 25/25 °C sank im Vergleich zur Kontrollgruppe der Fettgehalt der Schösslinge bei allen Leguminosenkeimlingen geringfügig, er stieg jedoch wieder bei 30/30 °C. Keine Korrelation war zu finden zwischen Fettgehalt der Wurzeln und der Reaktion der Genotypen auf Hitzestress. Der Anteil abnormer Keimlinge und die Verteilung der Hauptwurzellänge bringen die Toleranz der Genotypen gegenüber Hitzestress zum Ausdruck. Im frühen Keimstadium könnte die Selektion zur Verbesserung der Hitzetoleranz nur für Bohnen bei hoher Temperatur erreicht werden.

Schlagworte: Bohne, Sojabohne, Erbse, Hitzestress, Keimung.

Summary

In this work the effect of high germination temperature has been investigated on seed quality of soybean cultivars and bean genotypes grown under irrigated and non-irrigated, dry conditions. After four and eight days we expressed the degree of drought tolerance by the rate of abnormal and diseased seedlings. The high temperature significantly increased the number of abnormal seedlings, which come from seeds of both species grown under non-irrigated, dry conditions. The chemical substances and root development of seedlings from bean, soybean and pea grown under non-irrigated condition were investigated at 20/10 °C as control temperature 25/25 °C (day/night) and 30/30 °C (day/night). Moderate heat stress (25/25 °C) caused considerable decrease in root length of seedlings from large seeded bean genotypes but did not in soybean cultivars. Rising temperature did not change the protein contents of shoot in either species but increased the dry matter significantly except the pea. At 25/25 °C the fat content of shoot in all legume seedlings decreased slightly compared to the control but it increased again at 30/30 °C. We did not find correlation between the fat content of root and the reaction of genotypes to heat stress. The rate of abnormal seedlings and the distribution of primary root length expressed the tolerance of genotypes to heat stress. At the early stage of germination the selection to improve heat tolerance in only beans could be achieved at high temperature.

Key words: bean, soybean, pea, heat stress, germination.

pea caused low individual seed weight but it had no influence on seed vigour.

The root system has an important role in surviving water stress. Although the roots of soybeans are about three times bigger than those of beans, both soybean and bean cultivars react to water deficiency stress with a considerable mass loss of 42–45 % (NEMESKÉRI, 2001).

The drought tolerance, including water and heat tolerance is difficult to investigate separately under field conditions. GRZESIAK et al. (1996) reported that the drought tolerance of seedlings tested in the laboratory significantly correlated with that in the field experiments. BERTHOLDSSON (1989) had the same conclusion as the measurements of early root growth in pea correlated with yield stability under field conditions. The intensity of root growth is also correlated with the seed size. In lupine, SIDIRAS and KARSIOTI (1996) found that the root growth of large seeds was more intensive than that of small seed. It was similar to KRISTENSEN's (1998) finding i.e. the smallest seed sized pea genotypes showed the most shallow early rooting.

The physiological quality (as protein, carbohydrate and lipid contents) of seedlings suffering from lack of water changed, which can affect the root development. According to studies by SIDIRAS and KARSIOTI (1996) at the first stage of root growth in lupine the total lipid content had larger effects on the formation of secondary roots than other substances. Investigating the starch hydrolysis in the lateral roots of dicotyledons GENKEL (1982) revealed the capacity of beans to endure the loss of water is smaller than of the overheating. He found that the starch contents of the lateral root cells in bean varieties differed under heat- and water-stress. The total lipid content of pea roots decreased when the plants suffered from lack of water (KUMAR et al., 1990).

This work is to investigate the effect of high germination temperature on seed quality of bean and soybean grown under irrigated and non-irrigated conditions and to evaluate the heat stress tolerance of seedlings in bean and soybean and pea, to reveal if the heat stress tolerance of varieties could be measured by the ratio of abnormal germs and dead seeds.

2. Materials and Methods

I. Experiment

Sixteen of the soybean varieties of different origin and maturity groups and twenty of breeding lines of bean with small and large seed size were investigated in the field experiments under irrigated and non-irrigated growing conditions from 1996 to 1997. The seed samples were randomly taken from harvested seeds in every year and the normal seeds were used for germination tests in laboratory. The seeds were treated with water plus 0.3 % chlorine to prevent microbial infection. For the germination tests, 4 x 25-seed samples were used in rolled paper towels inside the plastic bags then placed into the thermostat. The standard germination test as a control, was used to evaluate the seed vigour of soybean and bean varieties when the seeds were maintained at a constant 24 °C for 8 days as described in Rules for Testing Seeds. The drought tolerance of bean and soybean varieties was evaluated at 28 °C. On the 4th and 8th

day of germination period we determined the percentage of normal, abnormal seedlings and diseased, dead seeds while supplementing the consumed water. Abnormal seedling category covered those whose primary root and secondary roots were under-developed or absent, the hypocotyl was cracked or decayed, the epicotyl was decayed or terminal bud was missing. The data were analysed by two factorial variance analyses.

II. Experiment
From 1998 to 2000, the germination of bean soybean and pea seeds grown under non-irrigated condition was performed under controlled environments in the laboratory. The bean varieties investigated were small seeded 'Start', 'Debreceni gyöngy' and 'R86139'; the other genotypes had large seed sizes. 'Tyrkyz' variety of peas was large seeded but 'Debreceni galamb' variety had small seeds. The soybean cultivars were the early maturing 'McCall', 'BS-38', the mid-early maturing 'Evans' 'HM-262' and the late maturing 'Borza'. All of them had approximately similar seed size. The germination tests were carried out as above mentioned. The heat treatments were as follows: 20/10 °C (day/night) regarded as control, 25/25 °C (day/night) as moderate heat stress and 30/30 °C (day/night) represented the serious heat stress. For the germination tests, 2x25-seed samples were used to measure the length of primary root so that we can analyse the effect of high germination temperature on root development of the seedlings on the 4th and 8th days of germination periods.

We select two bean and pea varieties with different seed sizes and three cultivars of soybeans for chemical analysis. The protein fat and dry matter contents were measured in all seedlings. The results were appraised by using SPSS statistical program. Regression analysis was performed to reveal the relationships between the seed size and the length of primary root.

3. Results

I. Experiment
The germination of twenty of bean genotypes and sixteen of soybean cultivars grown under irrigated and non-irrigated conditions were investigated on high temperature. On 4th and 8th day of germination period the seedlings were classified to the groups including healthy abnormal germs and diseased, dead seeds, respectively. Independently of growing conditions, there were significant differences in the ratio of abnormal and diseased germs between the bean varieties at both times of germination. The temperature x variety interaction expressed the heat sensitivity of genotypes was significant ($P < 0.001$) concerning on abnormal and diseased germs in the bean seeds grown under non-irrigated conditions. This was significant concerning on mainly the ratio of diseased germs in the case of soybean.

The effect of high germination temperature on the seed quality of bean and soybean grown under different conditions could be seen in table 1. At 28 ºC the ratio of abnormal seedlings from the seed grown under non-irrigated conditions was larger than at 24 ºC. Significant differences in abnormal seedlings on the 4th and 8th days of germination could only be revealed in bean genotypes grown under non-irrigated conditions (table 1). The ratio of abnormal seedlings in the bean genotypes was larger (38.81 %) than in soybeans (29.81 %). Only a few bean genotypes were tolerant to high germination temperature. The percentage of abnormal seedlings was close to the average of the varieties (38.81 %) in these genotypes. In contradistinction to beans, the tolerance to heat stress in soybeans concerning on the ratio of abnormal seedlings could not be reliably evaluated at the early stage of germination. Some of the middle-early maturity groups and one of the late maturity cultivars have high tolerance to heat stress on 8th day of germination.

The high temperature resulted in much more dead seeds in beans grown under irrigated conditions than in the non-irrigated conditions. The number of dead soybean seeds was smaller than the number of dead beans, independently of growing conditions (table 1). Soybean seeds of varieties 'Panther' and 'Borza' are susceptible to cracking, which resulted in larger percentage of dead seeds. The findings reveal that the seeds grown under non-irrigated conditions produce larger abnormal seedlings in beans at high germination temperature than in soybeans. Selection of heat tolerant bean genotypes based on the ratio of abnormal seedlings could already be achieved at early stage of germination at 28 °C (NEMESKÉRI, 2004). It appears that heat tolerance of soybeans cannot be improved because of absence of significant differences between varieties in their abnormal germ percentage.

II. Experiment
The growth of legumes cultivated in the light soil warming up easier could be delay because of slow development of the root system. From the previous experiment, the selection of bean and soybean genotypes based on seed size and heat tolerance were taken to test them at different temperatures. We

investigated the length of primary root of seeds grown under non-irrigated conditions. During the germination, the 30/30ºC (day/night) temperature hampered the development of primary root in pea to the greatest extent and the slightest in soybean (table 2). On the 4^{th} day of germination under permanent high temperature the decrease of root length of bean with small seed size was smaller (54.7 %) than that of large seeded beans (62.8 %) compared to the control. At 30/30 °C the length of root in small seeded pea variety decreased 69.3 percentage as compared to the control (20/10 °C) however the decrease was larger (73.8 %) in the large seeded one. At the later stage of germination on the 8^{th} day, the differences between the pea varieties disappeared but it increased among the beans. We found the growth of primary root of 'Borza' variety from the late maturity groups of soybeans was much more sensitive to high germination temperature than that of early or middle-early maturity ones.

We further investigated the relationship between the seed size and the length of primary root at different germination temperatures. On the 8^{th} day of germination at 20/10 °C (day/night) the increase in the thousands grain weights of beans correlated with the length of primary root ($r = +0.913$) as seen in figure 1. During the moderate heat stress as 25/25 °C (day/night) the thousands grain weights of bean increased while the length of root decreased particularly over 450 g of thousands grain weights ($r = -0.756$) (figure 1). Increasing the heat stress, there was not significant correlation between the seed size and the growth of root in the beans. We also found significant correlation between the seed size of soybeans and the length of root at different heat treatments. Increasing seed size over 150 g of thousands grain weights the length of root increased in soybean ($r = +0.787$) under moderate heat stress but the development of root was delayed ($r = -0.863$) at serious heat stress as seen in figure 2.

The varieties and genotypes were arranged by Duncan's homogeneous test into the groups shown the differences in adaptability of seedlings for the temperature. The root system of four-day-old seedlings from large seeds of bean was the most sensitive to changes of germination temperature. During germination this range was changed but the most of bean genotypes could be classified into the somewhat heat sensitive 2–3 groups (tables 3 a and b). The root of small seeded bean varieties had the best adaptability to changes of temperature. At early stage of germination on the 4^{th} day, the development of root of soybeans was less sensitive to different heat stress than that of beans. The early and mid-early maturing soybean cultivars such as 'BS-38' and 'HM-262' belonged to the group most sensitive to heat stress at both early and late periods of germination (table 4). In the case of pea the regression analysis and homogeneous test could not be performed because of few numbers of varieties.

At permanent high temperature the growth of root seemed to be slow and the chemical substances of shoot and root changed. The largest dry matter content was measured in the shoots of four-day-old pea seedlings and the most fats in their roots. At a farther stage of germination the dry matter content deceased significantly in the shoots but the protein content increased in both bean soybean and pea. The largest increase in protein content was in the shoot of beans. The greatest differences in the fat contents of seedlings could be detected; the accumulation of fat into the shoot of peas was large contrary to the soybean where it decreased significantly.

We used the data of eight-day-old seedlings of all species for comparison because few four-day-old pea seedlings were available for analysis at 30/30 °C. At high temperature the dry matter content of shoot increased significantly in bean and soybean compared to the control (20/10 °C (day/night) but the decrease of dry matter in root could be measured in soybean seedlings only (table 5). Increasing the temperature, there were differences in fat content of shoot in all seedlings but did not affect in the protein content. Moderate heat stress (25/25 °C day/night) resulted significant decrease in fat content of shoot only in soybean compared to the control. Under this condition, we found a small increase in fat content of roots in bean and pea but it decreased in the soybean. Increasing temperature up to 30/30 °C, the fat content of shoot and root increased except the pea where it decreased a little bit in the root (table 5). There were differences in dry matter of shoot between the bean and soybean varieties. The differences in protein content were significant between the bean varieties while the differences in fat content could be demonstrated between the soybean varieties (table 6).

4. Discussion

The tolerance based on the ratio of abnormal germs due to the high temperature was lower in beans than in soybeans. The differences in abnormal seedlings and dead seeds in bean genotypes were significant on 4^{th} day at early period of germination as well. Only a few bean genotypes were tol-

Table 1: Seed quality of bean and soybean grown under irrigated (I) and non-irrigated (D) conditions at different germination temperatures[a]
Tabelle 1: Saatqualität von Bohnen und Sojabohnen bei unterschiedlichen Keimtemperaturen mit (I) und ohne (D) Bewässerung

Temperature °C	Days	Growing Ways	BEAN			SOYBEAN		
			Healthy %	Abnormal germs %	Dead seeds %	Healthy %	Abnormal germs %	Dead seeds %
24	4	I	76.20	13.30 *	10.50 *	86.67	9.83	3.50
	4	D	89.23	7.29 *	3.48 *	88.84	6.13 *	5.03
	8	I	49.40	16.10	34.50 *	58.50	21.17 *	20.33
	8	D	57.90	23.20 *	18.90	58.24	15.13	26.63 *
28	4	I	38.20	18.70	43.10 *	74.16	11.17	14.67
	4	D	64.15	21.95 *	13.90 *	74.35	9.25	16.40
	8	I	7.40	5.00	87.60 *	32.50	30.67 *	36.83 *
	8	D	10.74	38.81 *	50.45 *	33.94	29.81	36.25 *

[a] The values are the average of 2 years of experimental data
* P< 0.001 among the varieties

Table 2: Effect of high germination temperature on root development of grain legumes[a]
Tabelle 2: Effekte hoher Keimtemperatur auf die Wurzelentwicklung von Körnerleguminosen

Species	4-day-old seedlings Root length (cm)			SHT/Control %	8- day-old seedlings Root length (cm)			SHT/Control %
	Control [b]	**MHT** [c]	**SHT** [d]		**Control** [b]	**MHT** [c]	**SHT** [d]	
BEAN	8.69 **a**	7.20 **b**	3.21 **c**	***36.94***	16.96 **a**	11.52 **b**	5.30 **c**	***31.25***
PEA	5.98 **a**	3.95 **b**	1.69 **c**	***28.26***	15.04 **a**	9.37 **b**	3.04 **c**	***20.21***
SOYBEAN	12.13 **a**	9.17 **b**	7.41 **c**	***61.09***	16.56 **a**	14.15 **b**	3.10 **c**	***54.95***

The values in a row having different letters are significantly ($P < 0.05$) different
[a] The values are the average of 3 years of experimental data
[b] Control = 20 °C/10 °C (day/night)
[c] MHT= 25 °C/25 °C (day/night) moderate heat stress
[d] SHT = 30 °C/30 °C (day/night) serious heat stress

Table 3: Root lengths of four-day-old seedlings (a) and eight-day-old seedling (b) of bean are arranged by Duncan's homogeneous test into groups on the average of temperatures
Tabelle 3: Wurzellängen vier (a) und acht (b) Tage alter Bohnenkeimlinge entsprechend dem Duncan-Homogenitätstest in Gruppen nach den Durchschnittstemperaturen angeordnet

Table 3 (a)

Bean varieties	1000 seeds weight (g)	Groups 1	2	3	4
Coco	362	4.43			
D830/1/35	478	4.55			
Debreceni tarka	467	4.70			
D830/1/31	462	5.19	5.19		
R86139	186	5.23	5.23		
Debreceni gyöngy	205		5.57	5.57	
D1076/SE	395		5.77	5.77	
D1076/6	435			6.17	
Start	210				7.25
P < 0.05		0.55	0.15	0.12	1.00

Table 3 (b)

Bean varieties	1000 seeds weight (g)	Groups 1	2	3	4
D830/1/35	478	7.89			
D830/1/31	462	7.96			
D1076/6	435	8.04			
Coco	362	8.46	8.46		
D1076/SE	395	8.95	8.95	8.95	
R86139	186	9.07	9.07	9.07	
Debreceni tarka	467		9.47	9.47	
Debreceni gyöngy	205			9.89	
Start	210				12.20
P < 0.05		0.10	0.15	0.18	1.00

Table 4: Root lengths of four-day-old seedlings (a) and eight-day-old seedlings (b) of soybean are arranged by Duncan's homogeneous test into groups on the average of temperatures
Tabelle 4: Wurzellängen von vier (a) und acht (b) Tage alten Sojabohnenkeimlingen entsprechend dem Duncan-Homogenitätstest in Gruppen nach Durchschnittstemperaturen angeordnet

Soybean varieties	1000 seeds weight (g)	**a**		**b**		
		Groups		Groups		
		1	**2**	**1**	**2**	**3**
HM-262	169	7.24		11.44		
BS-38	153	7.89		11.21		
Borza	184		9.20	12.44	12.44	12.44
McCall	132		9.77		12.69	12.69
Evans	156		9.68			13.11
$P < 0.05$		0.11	0.19	0.72	0.69	0.34

Table 5: Effect of temperatures on the distribution of substances of the eight-day-old seedlings
Tabelle 5: Auswirkung der Temperatur auf die Keimlingszusammensetzung bei acht Tage alten Keimlingen

Species	Temperature °C*	Shoot			Root	
		Dry matter %	Protein %	Fat %	Dry matter %	Fat %
BEAN	20/10	14.92 b	32.98	1.14	8.24	0.60
	25/25	12.94 c	33.02	0.74	9.39	0.90
	30/30	16.90 a	34.24	1.22	12.64	0.98
	LSD $P_{0.1\%}$	1.54				
PEA	20/10	25.30	27.61	1.12 ab	9.14	1.27
	25/25	25.88	27.49	0.78 b	13.63	2.14
	30/30	28.93	29.76	1.54 a	15.79	1.88
	LSD $P_{5\%}$	–	–	0.50		
SOYBEAN	20/10	11.54 b	41.57	4.54 a	12.70 b	0.70
	25/25	9.78 c	43.94	2.66 b	13.34 a	0.55
	30/30	13.44 a	47.00	3.98 ab	10.61 c	0.90
	LSD $P_{5\%}$	1.48		1.36	0.52	
	LSD $P_{0.1\%}$	1.70				

The values in a column having different letters are significantly different

* 20/10 °C (day/night) = control temperature, **25/25 °C** (day/night) = moderate heat stress, **30/30 °C** (day/night) = serious heat stress

Table 6: Effect of high temperature treatments on the substances of shoot in the eight-day-old seedlings of different varieties
Tabelle 6: Der Effekt hoher Temperatur auf die Sprosszusammensetzung von acht Tage alten Keimlingen verschiedener Sorten

Shoot	Species	*Varieties*	C	MHT	SHT
Dry matter %	BEAN	*Start*	8.10 ***	7.91 ***	10.56 ***
		Debreceni tarka	21.74	17.97	29.57
Protein %	BEAN	*Start*	38.47	35.44	36.69
		Debreceni tarka	27.49 ***	30.60 ***	29.36 ***
Fat %	BEAN	*Start*	1.38	0.65	1.23
		Debreceni tarka	0.91	0.83	1.20
Dry matter %	PEA	*Debreceni galamb*	23.45	25.88	28.93
		Tyrkyz	27.16	28.43	28.90
Protein %	PEA	*Debreceni galamb*	27.12	27.49	29.76
		Tyrkyz	20.09	21.09	26.35
Fat %	PEA	*Debreceni galamb*	1.07	0.72	1.54
		Tyrkyz	1.18	0.83	1.35
Dry matter %	SOY-BEAN	*McCall*	8.80 ***	8.46 ***	10.97 ***
		Evans	11.90	9.15	13.22
		Borza	13.92	11.73	16.12
Protein %	SOY-BEAN	*McCall*	41.96	44.04	46.91
		Evans	38.73	41.88	44.59
		Borza	44.03	45.92	49.49
Fat %	SOY-BEAN	*McCall*	3.10 **	1.92	3.52
		Evans	5.38	2.78	3.58
		Borza	5.16	3.28	4.84

** $P < 0.01$
*** = $P < 0.001$ means significant differences between the varieties at the same temperature
C = 20/10 °C (day/night) control temperature
MHT = 25/25 °C (day/night) means moderate heat stress
SHT = 30/30 °C (day/night) means serious heat stress

erant to high germination temperature. On contrary to the bean, the heat tolerance of soybean cultivars could only be reliably evaluated on the 8th day of germination. In the case of bean seeds grown under irrigated condition the number of diseased germs and dead seeds increased significantly at 28 °C compared to the control (table 1). This finding is coincided with that of KEIGLEY and MULLEN (1986) i.e. the high temperatures (32/28 °C day/night) during seed filling

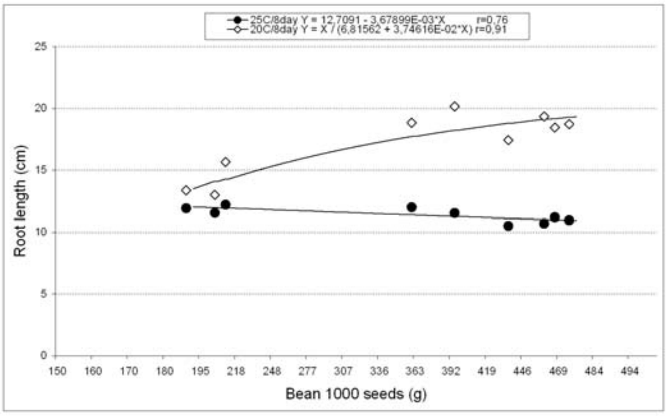

Figure 1: Relationship between the seed size and length of root in eight-day-old bean seedlings at 20/10 °C and 25/25 °C

Abbildung 1: Zusammenhang zwischen Samengröße und Wurzellänge acht Tage alter Bohnen-Keimlinge bei 20/10 °C und 25/25 °C

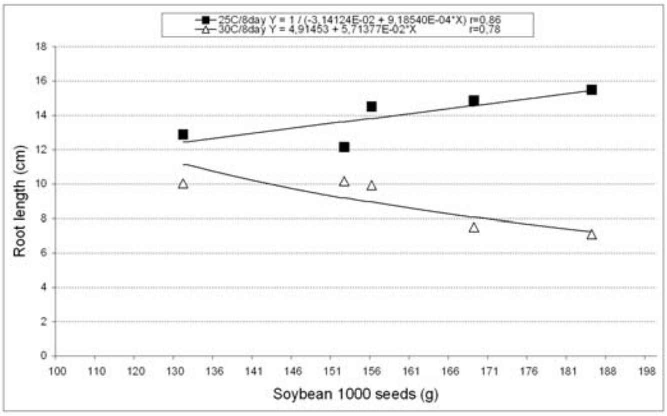

Figure 2: Relationship between the seed size and length of root in eight-day-old soybean seedlings at 25/25 °C and 30/30 °C

Abbildung 2: Zusammenhang zwischen Samengröße und Wurzellänge acht Tage alter Sojabohnen-Keimlinge bei 25/25 °C und 30/30 °C

reduce the germination of seeds from well-watered plants. This may be explained with that the development of root in bean seedlings has already stopped on the 4th day of germination at high temperature. Later the death of diseased germs attributed to injuries of cell membrane resulted by high temperature. Not the temperature, but the varieties affected on the number of diseased germs in soybean; the early maturing varieties produced low vigorous and diseased germs but ‘Borza’ and ‘Panther’ varieties of late maturity group did lot of dead seeds.

The effects of water and heat stresses on the genotypes are difficult to investigate separately under field environments. The drought during seed filling results much more deformed and unviable seeds in the bean genotypes with large seeds than in the small seeded ones (NEMESKÉRI, 1994). The seed size has indirect influence on the yield quantity (NEMESKÉRI, 2000) and quality of small and large seeded beans (WHITE and GONZALES, 1990; SEXTON at al., 1994). The possible explanation to the above is that the larger seeded bean lines need a lower optimum temperature for cell division and seed growth (LAING et al., 1984; DEKHUIJZEN and VERKERKE, 1986). The growth of the germinated seeds indicates that tissue tolerance to high temperatures extends beyond photosynthetic tissue and is also an important character of root and hypocotyls tissue (GRZESIAK et al., 1996).

As the finding by BERTHOLDSSON (1989) the early root growth in pea correlated with yield stability under field environments so we measured the growth of root in different seed size varieties under stress conditions. In the case of bean with large seeds, the development of root was generally more intensive than in small seeded genotypes. This finding coincided with that of SIDIRAS and KARSIOTI (1996) and KRISTENSEN (1998) i.e. the root length was related to seed size. We found the moderate heat stress (25/25 °C day/night) reduced the development of root in beans particularly over 450 g thousand-grain weight (th.g.w.). There was no correlation between the seed size and root length of soybean at control. However, the differences in the thousands grain weights of soybeans were not considerable we found significant correlation between seed size and the root length at different heat treatments.

Moderate heat stress, contrary to beans, did not delay the large seeded soybean’s root growth. Serious heat stress (30/30 °C day/night) decreased the length of root of soybeans with large seeds over 150g th.g.w. while the growth of root independently of the seed size was ended in beans. Our results support SMITH et al.’s findings (1988) that high temperature causes more damages to the root development of bean than that of soybean. However, the differences in the reaction to heat stress could be demonstrated between the bean genotypes. The varieties and genotypes could be arranged in the groups based on the length of primary root. The root system of small seeded beans such as ‘Start’ and ‘Debreceni gyöngy’ varieties had the best adaptability to the change of temperature (table 3). The seedlings from small seeded ‘Debreceni galamb’ pea variety, similarly to beans, were less sensitive to high temperature than the large seeded ‘Tyrkyz’ variety. The development of roots of early maturing soybeans such as ‘BS-38’ and mid-early ‘HM-262’ was more sensitive to the change of temperature than of late maturing cultivars (table 4).

We expected the chemical substances of seedlings could be explained by the reasons of these differences. Lipid content had an important role in the root growth (SIDIRAS and KARSIOTI, 1996) under water stress (KUMAR et al., 1990). We supposed that the protein or lipids were able to stop the dehydration of tissues, simultaneously ensured large energy for the growth of seedlings. No differences could be shown in protein content of shoot of seedlings either in bean soybean and pea varieties during the heat stresses. In all species the dry matter content of shoot was considerably less in the small seeded varieties than in the large seeded ones. The high germination temperature caused a significant increase in dry matter of shoot from bean and soybean but decreased it in the root of soybean seedlings (table 5). Increasing temperature caused slight changes in fat contents of both shoot and root of seedlings. According to studies by KUMAR et al. (1990) the total lipid content of green pea roots decreased according to the varieties when the plants suffered from lack of water. On contrary to our expectation, correlation between the fat content of root and the reaction of seedlings to heat stress could not be shown. The fat level of root in bean and pea seedlings was slightly increased at moderate heat stress compared to the control temperature however there were no differences between the genotypes. There were no significant differences in fat content of root between the soybean cultivars either.

Summing up, the abnormal seedling occurrence increased in soybean and bean when their seeds were produced under dry growing conditions and are germinated at high temperature. The differences in abnormal seedlings and dead seeds in bean were more significant than in soybean varieties. The significant differences in abnormal seedlings of bean genotypes could be revealed on the 4^{th} day of germination at high temperature. Disturbed root development has a significant effect on the formation of abnormal seedlings. The ratio of abnormal seedlings and the distribution of primary root length show the tolerance of varieties to heat stress. Moderate heat stress caused a considerable decrease in primary root length of large seeded bean genotypes but did not in the soybean cultivars. Rising temperature did not change the protein contents of shoot but increased the dry matter content significantly except the pea. Serious heat stress (30/30 °C day/night) increased the dry matter levels of shoot only in the early maturing 'McCall' soybean variety and small seeded beans. Under moderate heat stresses (25/25 °C day/night) the fat content of shoot slightly decreased in all species compared to 20/10 °C but rising up 30/30 °C it increased again. On contrary to our expectation, we did not find correlation between the fat content of root and the reaction of seedlings to heat stress.

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