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Response to Inoculation and Sowing Date of Soybean Under Bafra Plain Conditions in the Northern Region of Turkey*

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Abstract: The Bafra Plain (latitude 41^0 35' N; longitude 35^0 56' E) which located surrounding of Kızıl Irmak delta in the northern Turkey, has a short plant growing season for spring sowings. However, the soils of the region (about 80 000 ha) may have an important soybean [*Glycin max* (L.) Merr.] production potential with using the earliest or mid–earliest cultivars. Field experiments were conducted to determine the optimum sowing date of soybean, and effects of inoculation and sowing date on the yield and yield components. P–9292 soybean cultivar was evaluated either inoculated with *Rhizobium japonicum* or not inoculated at 3 sowing dates for 1991 and 1992 and 4 sowing dates for 1993 at Bafra, Samsun. The experimental design was a randomized block in a split plot with four replications. Both seed inoculation and early sowing increased seed yields for each year. With earliest sowings in 1991, 1992 and 1993 seed yields were obtained as 2728, 2786 and 2779 kg ha^{-1}, respectively which were 969, 614 and 887 kg ha^{-1} more than the latest sowings. Duration of periods between VE–R1, R1–R3 and VE–R8 were found more closely related with high yields than nodule number, plant height and 100–seed weight. Early–May to mid–May was the optimum sowing period of soybean for Bafra Plain.

Türkiye'nin Kuzeyinde, Bafra Ovası Koşullarında Soya Fasulyesinin Aşılama ve Ekim Zamanına Tepkisi

Özet: Türkiye'nin kuzeyinde Kızıl Irmak deltasının çevresinde bulunan Bafra Ovası (41^0 35'K; 35^0 56' D), yazlık ekimler için kısa bir bitki büyüme mevsimine sahiptir. Bununla birlikte 80.000 ha olan bölge toprakları, ekenci veya orta erkenci çeşitlerin kullanılmasıyla önemli bir soya [*Glycine max* (L.) Merr.] üretim potansiyeline sahip olabilir. Bafra Ovası'nda soyanın optimum ekim zamanını belirlemek, aşılamanın ve ekim zamanının soyanın verimi ve verim komponentleri üzerine etkisini ortaya koymak için, P–9292 soya çeşiti ile tarla denemeleri yürütülmüştür. Dört tekrarlamalı "Bölünmüş Parseller Deneme Desenine" göre kurulan denemelerde, *Rhizobium japonicum* ile aşılı ve aşısız muamele edilen tohumlar 1991 ve 1992 yıllarında 3, 1993 yılında ise 4 farklı tarihte ekilmişlerdir. Tohum aşılaması ve erken ekim her üç yılda da tohum verimini artırmıştır. 1991, 1992 ve 1993'de yapılan ilk ekimlerden alınan 2728, 2786 ve 2779 kg ha^{-1} verimler, en geç ekimlere göre sırasıyla 969, 614 and 887 kg ha^{-1} daha fazla bulunmuştur. VE–R1, R1–R3 ve VE–R8 peryodları ile yüksek verim arasındaki ilişkiler, nodül sayısı, bitki boyu ve 100–tohum ağırlığına göre daha yakın bulunmuştur. Bafra ovası için en uygun soya ekim zamanı 1–15 Mayıs tarihleri olarak belirlenmiştir.

Introduction

Soybean [*Glycine max* (L.) Merr.] is the third important oil seed crop following sunflower and cotton in Turkey. It is mostly produced as a second crop in the southern and south–eastern regions of Anatolia which have a production capacity about 150–200 thousand tones per year. In the north, Bafra Plain (surrounded by Kızıl Irmak delta) which has a short plant growth season for spring sowings from early–May to mid–September, can be a production potential of soybean with using the earliest or mid–earliest cultivars. Unfortunately, soybean production is not developed in the region because of economics when compaired to the production of crops such as wheat, tobacco, corn, sunflower, rice and sugar beet. On the other hand, on some areas of the Bafra Plain which has about 80 000 ha, the irrigation systems are not established sufficiently.

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Inoculation of soybeans with efficient strains of *Rhizobium japonicum* may increase yields in areas where the bacteria are not already present. Several researches reported that significant yield increases were obtained by inoculation of soybean with appropriate bacteria before sowing (1, 2, 3, 4). However, inoculation may not be required in fields where soybean have been grown and inoculated for many years (5). Ham et al. (6) showed that, soybean yields were not significantly increased by inoculation, because of the uninoculated seeds were adequately nodulated by rhizobia which were in the soil from previous soybean crops.

The seed yields of soybean decrease with late sowings. This decreasing in seed yield was positively correlated with reductions in the number of branches per plant, number of pods per plant, number of seeds per plant and seed weights at the late sowing (7, 8, 9, 10, 11). Johnson et al. (12) attributed most of the differences in plant responses at different sowing dates to differences in the day length (photoperiod). Board and Hall (13) showed that, premature flowering induced by short photoperiods is one factor causing the reduced plant size and yield reductions from late sowing.

The purpose of this study was to determine the optimum sowing date of soybean under Bafra Plain conditions. In addition, the effects of seed inoculation with *R. japonicum* and sowing dates on yield and other agronomic characters of the plant were investigated.

Materials and Methods

Field experiments were conducted during the 1991, 1992 and 1993 at the Bafra Plain (latitude 41^0 35' N; longitude 35^0 56' E), near Samsun. The soil at the experimental site was slightly alkali, rich in phosphorus and potassium, medium in organic matter and lime content. Soil texture was clay–loam. In general, the period between early May and late September is dry, total rainfall of 199.4 mm, however the open–pan evaporation is 845.5 mm in the region (14). Rainfall and open–pan evaporation indicate that the crops subject to various degrees of water deficit during this five months. Heavy rains begin after September.

Values of mean temperature in a month were similar at all years of the study during the growth period of soybean. But, monthly total rainfalls showed great differences. Also, the extreme rainfall in May of 1991 (114.6 mm) prevented early plantings. There was no rainfall in August, 1992 (Table 1). A lot of the September rainfall is observed over the mean of long years (47.9 mm) after mid–September at three years of the study, too.

Mid–earliest soybean cultivar (P–9292) which is resistant to lodging, pod shattering and seed shedding, was used in the experiment. Seed inoculation was performed before sowing (15), using 10 g kg^{-1} soybean seed (approximately $1x10^6$ bacterial cells per seed). The inoculum containing the strains of *R. japonicum* was obtained from the Soil–Fertilizer Research Institute, Ankara. The experimental design was a randomized block in a split plot arrangement with four replications. Main plots were inoculation treatments; inoculated (I) and uninoculated (UI), and sub–plots were the planting dates (Table 2). The dimension of each plot was 5 by 2 m and consisted of four rows with a row spacing of 50 cm and seeding rates of 33 seeds m^{-1} was used. Fertilizer at the rate of 20 kg ha^{-1} as ammonium nitrate was applied at sowing. Generally, following each sowing, irrigation was done to obtain a good field emergence. However, irrigation possibility could not found for mid–June sowing of 1991 and the last two sowings of 1992.

Table 1. Monthly Mean Temperatures and Total Rainfalls During the Growing Period of Soybean in 1991, 1992 and 1993 at the Bafra Plain, Samsun.

	Mean temperature (°C)			Rainfall (mm)		
Month	1991	1992	1993	1991	1992	1993
May	14.5	13.2	14.5	114.6	17.8	37.6
June	18.9	19.7	19.5	49.6	31.9	71.0
July	23.2	21.2	20.9	20.0	37.7	19.8
Aug.	22.6	23.4	22.5	21.1	00.0	34.7
Sept.	17.6	17.6	18.4	71.2	65.7	83.1
Oct.	15.4	15.1	–*	79.6	83.3	–*

* The were no values because of the growth period of soybeans had been completed before October, 1993.

Table 2. Sowing Dates of Soybeans for a 3 Year Period.

Sowing times	Days of month		
	1991	1992	1993
Early May	–	–	6
Mid May	–	14	17
Late May	31	27	27
Early June	10	9	6
Mid June	18	–	–

Dates of emergence, flowering, pod filling and maturity were recorded at the VE, R1, R3 and R8 stages (16), respectively. Each year, at seed filling (R6), 10 plants were taken at random from each plot to evaluate the number of nodules distributed throughout the entire root system. At harvest, plant height, number of seeds per plant, 100–seed weight and seed yield (adjusted to 13% moisture content) were determined for each plot. Analysis of variance was used to examine the effect of inoculation, sowing date and inoculation x sowing date interactions for each year. Means were compared using the least significant differences (LSD) at 0.05 level of probability. Correlations between yield and some growth characteristics were calculated for each combination of inoculation–sowing date.

Results and Discussion

Phenological Data

Table 3 shows the durations and dates of emergence, flowering, pod filling and maturity of soybeans grown in 1991, 1992 and 1993. The time for seedling emergence varied between 7 to 20 days depending on the sowing dates and years. In addition to not been irrigated, the hight tempratures and unrainy days from sowing time to mid–June delayed the seedling emergence for May 27 sowing in 1992. All of the 31.9 mm June rainfall (Table 1) occured after June 13. Sowings after mid–May were began to flowering after July 20. Sowing date affected the reproductive growth period, especially late sowings reduced this period. The main reason of this was the shortened day lengths, because photoperiod affects all phases of the soybean plant and premature flowering and pod filling induced by short photoperiods (17, 18, 19). Plants of the early sowing of 1993 matured before the rainy season of mid–September. Whereas, sowings after mid–May in 1991, 1992 and 1993 were almost caught to the rains at the R7–R8 stages, which was not favorable conditions for harvest.

Nodule Number

Inoculation of seeds with *R. japonicum* increased the number of nodules per plant. Within inoculation

Table 3. Durations and Dates of Emergence, Flowering, Pod filing, Maturity and Total Growth Period of Soybeans Affected by Sowing Dates for a 3 Year Period.

Sowing date	Emergence		Flowering		Pod filling		Maturity		Growth period
	days[a]	date	days[b]	date	days[c]	date	days[d]	date	days[e]
					1991				
May 31	13	June 13	36	July 19	11	July 30	66	Oct. 4	126
June 10	7	June 17	36	July 23	10	Aug. 2	65	Oct. 6	118
June 18	16	July 4	29	Aug. 2	8	Aug. 10	63	Oct. 12	116
					1992				
May 14	11	May 25	39	July 3	14	July 17	70	Sept. 25	134
May 27	20	June 16	36	July 22	13	Aug. 4	55	Sept. 28	124
June 9	15	June 24	36	July 30	10	Aug. 9	55	Oct. 3	116
					1993				
May 6	10	May 16	48	July 3	18	July 21	48	Sept. 7	124
May 17	9	May 26	48	July 13	17	July 30	46	Sept. 14	120
May 27	9	June 5	45	July 21	17	Aug. 7	44	Sept. 17	115
June 6	8	June 14	43	July 26	16	Aug. 11	46	Sept. 27	113

[a] No. of days from sowing to emergence, [b] No. of days from emergence to flowering, [c] No. of days from flowering to pod filling, [d] No. of days from pod filling to maturity and [b] No. of days from sowing to maturity.

treatment mean; with I, 1.6 (1991), 1.2 (1992) and 1.5 (1993) times more number of nodules in comparision to UI were observed (Table 4). Plants grown on this clay–loam soil, produced fewer nodules in 1992 because of considerable shortage of rainfall at the nodulation stages. Ciafardini and Barbieri (20) reported that mobility of the symbiont inoculated onto the seed is very poor in clay soils, and the roots grow rapidly, being directed far from the inoculation points. Also, percolation water effects the movement of the bacterium in the soil. In 1992, the average number of nodules in the I and UI were similar within inoculation treatment mean and no effect of inoculation was found. However, the effect of inoculation was statistically significant in 1991 ($P<0.01$) and 1993 ($P<0.05$). Joshi et al. (1), Kim et al. (2) and Prodan et al. (21) also found increases in the nodule number with inoculated seed. First sowing dates in all years, produced the highest number of nodules. They were 21.4, 9.9 and 29.0 for 1991, 1992 and 1993, respectively, within sowing date mean. Delay in the sowings decreased these values significantly ($P<0.01$) for each year (Table 4). Inoculation x sowing date interaction was found significant ($P<0.01$) in 1991, where with the I treatment, early–June sowing produced 2.1 more nodules than the late–May sowing of the I treatment.

Plant Height

Average plant height was changed between 45 to 72 cm depending to the years and treatment combinations. However, inoculation treatments and inoculation x sowing

Table 4. Effects of Inoculation and Sowing Date on the Number of Nodule and Plant Height for a 3 Year Period.

	Nodule (no. plant^{-1})			Plant height (cm)		
Sowing date	1991	1992	1993	1991	1992	1993
I						
Early May	–	–	37.6	–	–	71.6
Mid May	–	10.1	25.5	–	55.5	64.9
Late May	24.8	7.7	11.9	49.2	54.1	65.9
Early June	26.9	4.1	17.6	47.8	49.3	655.1
Mid June	15.2	–	–	45.0	–	–
UI						
Early May	–	–	20.5	–	–	66.5
Mid May	–	9.8	18.9	–	54.4	68.6
Late May	18.0	4.6	11.4	49.9	57.2	58.6
Early June	13.7	4.2	12.4	48.8	52.7	61.6
Mid June	10.8	–	–	47.7	–	–
LSD (0.05)	3.3	NS	NS	NS	NS	NS
IT mean						
I	22.3	7.3	23.2	47.3	53.0	64.4
UI	14.2	6.2	15.8	48.8	54.8	63.8
LSD (0.05)	3.2	NS	6.2	NS	NS	NS
SD mean						
Early May	–	–	29.0	–	–	69.0
Mid May	–	9.9	22.2	–	54.9	66.7
Late May	21.4	6.1	11.6	49.6	55.6	62.2
Early June	20.3	4.1	15.0	48.3	51.0	58.3
Mid June	13.0	–	–	46.3	–	–
LSD (0.05)	2.3	1.9	6.4	2.0	3.4	6.0
C.V. (%)	11.6	25.5	31.5	3.9	5.9	9.0

Abbr: I=Inoculated, UI=Uninoculated, IT=Inoculation treatment, SD=Sowing date, NS=Not significant.

date interactions were not statisticaly significant. Plant heights were similar within inoculation treatment mean for each year. Sowing dates effected the plant height and they were decreased significantly ($P<0.05$ for 1991 and 1992; $P<0.01$ for 1993) through the delayed sowings. There was a difference of more than 10 cm between early-May and early-June sowings in 1993 (Table 4). This decreases in the plant height could be attributed to a shorter vegetative period (22, 23), and low canopy competition among the plants at the latest sowings.

Number of Seed and Seed Weight

There was no difference within inoculation mean for seed number in 1991 and 1992. However seed inoculation increased the number of seed by 1.2 times in 1993 and this was significat ($P<0.05$). The effect of sowing date on number of seed was significant ($P<0.01$) for 1992 and 1993 and, the mid–May (1992) and early–May (1993) sowings gave the highest number of seeds (Table 5). But, mid–June sowing of 1991 increased the number of seed (59.8). This increase was observed both I and UI plants. The reason of this was a few number of seedlings emerged in the plots due to the dry soil condition. Thus, they produced more branches and more pods and ultimately more seeds than the former sowings, because of less canopy competetion. However, this rising in the number of seed was not reflected to the seed yields of mid–June sowing in 1991.

Effect of inoculation was not significant on the 100–seed weight in 1992 and 1993, but is was significant ($P<0.05$) in 1991 and the I seed was 0.6 g heavier than UI seed within inoculation treatment mean (Table 5). Sowing date significantly ($P<0.05$ for 1991; $P<0.01$ for 1992 and 1993) effected 100–seed weight and the seeds from the first sowings were 0.6 g (1991), 3.9 g (1992) and 3.0 g (1993) heavier than the latest sowing dates (Table 5). This difference can be attributed to the longer period between R5 and R8, and a lot of nodule number per plant at the first sowings for each year. Inoculation x sowing date interaction was not significant for neither 100–seed weight nor seed number.

Seed Yield

Seed inoculation increased the yields at all years.

Table 5. Effects of Inoculation and Sowing Date on the Yield and Yield Components for a 3 Year Period.

Sowing date	Seed (no.plant^{-1})			100–seed weight (g)			Seed yield (kg ha^{-1})		
	1991	1992	1993	1991	1992	1993	1991	1992	1993
I									
Early May	–	–	58.0	–	–	23.2	–	–	2812
Mid May	–	35.9	42.5	–	24.9	20.2	–	2902	2664
Late May	43.5	39.9	42.5	23.9	20.1	19.9	3015	2714	2700
Early June	39.6	23.3	40.0	23.1	20.6	19.7	2529	2231	2321
Mid June	61.7	–	–	23.0	–	–	1719	–	–
UI									
Early May	–	–	58.7	–	–	22.3	–	–	2746
Mid May	–	42.5	31.4	–	23.8	21.5	–	2670	2410
Late May	46.4	31.5	31.1	22.9	19.8	20.4	2442	2446	2404
Early June	42.7	24.6	25.8	22.5	20.1	19.7	2479	2112	1464
Mid June	57.9	–	–	22.6	–	–	1800	–	–
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
IT mean									
I	48.3	33.0	43.9	23.3	21.9	20.7	2421	2616	2624
UI	49.0	32.9	36.7	22.7	21.2	21.0	2240	2410	2256
LSD (0.05)	NS	NS	6.3	0.49	NS	NS	NS	NS	218
SD mean									
Early May	–	–	58.3	–	–	22.7	–	–	2779
Mid May	–	39.2	33.2	–	24.3	20.8	–	2786	2552
Late May	44.9	35.7	36.8	23.4	19.9	20.1	2728	2580	2537
Early June	41.1	23.9	32.9	22.8	20.4	19.7	2504	2172	1892
Mid June	59.8	–	–	22.8	–	–	1759	–	–
LSD (0.05)	NS	6.5	6.6	0.5	0.9	0.8	283	273	392
C.V. (%)	30.3	18.1	15.6	1.9	3.7	3.5	11.1	10.0	15.3

Abbr: I=Inoculated, UI=Uninoculated, IT=Inoculation treatment, SD=Sowing date, NS=Not significant.

However these increases were not significant in 1991 and 1992, except 1993. In the third year of the study, yield was increased by 16.3 % reaching 2624 t ha^{-1} with I and it was significantly ($P<0.05$) different within inoculation treatment mean (Table 5). This result showed similarity to the findings of Joshi et al. (1), Kim et al. (2), İbrahim and Mahmoud (3) and Alibekova et al. (4). Early sowings increased yields. With earliest sowings in 1991, 1992 and 1993 seed yields were obtained as 2728, 2786 and 2779 kg ha^{-1}, respectively which were 969, 614 and 887 kg ha^{-1} more when compared to the latest sowings. This difference was statistically significant ($P<0.05$ for 1992; $P<0.01$ for 1991 and 1993) within sowing date mean (Table 5). When the earlier sowing dates are compaired, however, no significant differences in seed yields were found for each year. A significant interaction was not found between inoculation and sowing date.

In this study, duration of periods between VE–R1, R1–R3 and VE–R8 were always more closely associated with high yield (r=0.30, 0.29 and 0.37, respectively) than the number of nodule per plant (r=0.25), plant height (r=0.25) and 100–seed weight (r=0.23) for over 3 years (Table 6). This showed that, length of the durations of vegetative growth, flowering and maturity were more important in determining seed yield for each year. Plant height was more closely related with seed yield, too, in 1991 (r=0.62) and 1992 (r=0.57) but was not in 1993. While number of seed per plant was possitive correlated with yield (r=0.51) in 1993, it was negative correlated (r= –0.43) in 1991. This was a result of low plant density in the plots sown late which was mentioned before.

Decreased yields at the sowings after May probably is due to the moisture deficits during R5–R7 stages. Because, rainfall was low and evaporation was high during this period at the experimental site. Meckel et al. (24) and Smiciklas et al. (25) reported that drought stress often occours in soybean production areas during seed formation and seed filling, causing reductions in yield and seed quality.

Conclusions

The data presented above indicated that, there was a yield advantage to sowing soybeans at the Bafra Plain as early as possible, i.e. in early–May, due to the close correlation between high yield and growth durations. When sowing is delayed untill the early–June, the yield will decreased significantly. Late sown soybeans will mature around late–September or early–October are not suitable for the region because of unfavorable harvest weather conditions. In addition, rainy days after mid–September may be hazardous for the storage of seeds with high moisture content. If possible, especially in the late sowings, seedbed should be irrigated after sowing in order to obtain a good field emergence. Conversely, emergence may be delayed in the dry soil condition as occured at the first year of the study, due to the sensitivity of soybean seeds to the moisture at the germination stage. On the other hand, inoculation is essential to the establishment of a succesfull N_2–fixing symbiosis at the Bafra Plain which generally lacks indigenous soil *R. japonicum*. Additional research is necessary with earliest and mid earliest cultivars to understand which is better for the climatical condition of the region.

Table 6. Some Correlations Between Growth Characteristics and Seed Yield Within Each Year and Over Years (n=24 for 1991 and 1992, n=32 for 1993 and n=80 for over year).

Growth characteristics	Year			Over 3 year
	1991	1992	1993	
No. of nodule per plant at R6	0.69 **	NS	NS	0.25 *
Plant height at R8	0.62 **	0.57 **	NS	0.25 *
100–seed weight at R8	0.44 *	NS	NS	0.23 *
No. of seed per plant at R8	– 0.43 *	NS	0.52 **	NS
Vegetative duration (VE to R1)	0.81 **	0.46 *	0.55 **	0.30 **
Flowering duration (R1 to R3)	0.82 **	0.55 **	0.61 **	0.29 **
Maturity duration (VE to R8)	0.73 **	0.51 *	0.49 **	0.37 **

*, * * Significant at the 0.05 and 0.01 probability levels, respectively.

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