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IRRIGATION, PLANTING DATE AND INTRA-ROW SPACING EFFECTS ON SOYBEAN GROWN UNDER DRY FARMING SYSTEMS

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ABSTRACT

Two soybean cultivars (*Glycine maxima* (L) Merr.) differing in maturity period, leaf size and stem height were sown five times at fortnight intervals during the rainy season at four intra-row spacings under supplementary irrigation at one site and under rainfed conditions at another site in the central rainlands of Sudan. Cultivars responded differently to the system of production. Sowing date and moisture availability were the main factors controlling soybean production. The late maturing cultivar Semmes outyielded the early maturing cultivar Davis under supplementary irrigation whereas under rainfed conditions the reverse was true. Delayed sowings and wider intra-row spacings reduced grain of both cultivars under two systems of production. Irrigation increased grain yields and yield components of both cultivars markedly. The results seem to support the view that the optimum time of sowing both cultivars is over the period mid-June to mid-July, rather than a delayed date.

INTRODUCTION

There is considerable interest in developing soybean reseach in the arid and semi-arid regions of the world. Sudan has been facing a recurring shortage of vegetable oils for many years as the major edible oil seeds cotton, ground nuts and sesame are prone to inclement weather, moisture stress, pests and mis-management of cultural practices, which eventually precipitate crop losses.

Soybean plants need an adequate supply of water throughout the growing season and yields increase with the addition of supplemental water during flowering and pod development (Matson, 1964; Doss and Thurlow, 1974; Hinson and Hartwig, 1982; Cordonnier and Johnston, 1983; Heatherly and Elmore,1986)

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Cartter and Hartwig (1982) indicated that the time of sowing soybean has a profound effect on the height of the plant, degree of lodging, time of maturity, yield and yield components.

Among the management variables which can affect plant growth, and thereby the potential responsiveness of soybean to maximum interception of solar energy, moisture availability and soil nutrients, is intra–row spacing (plant population density). The optimal planting geometry for soybean is somewhat unsettled (Ramseur *et al.,* 1984) and erratic.

Where cotton is grown and oil processing facilities are available (as in Sudan), a supplemental oil crop, such as soybeans may allow continued use of the processing plant and may be an important incentive for growing the crop (Miller and Beard, 1967). Soybean research in the Sudan has started 10 years ago by introducing new varities from the U.S.A. and by participation in the International Soybean Programme (Ageeb and Khalifa, 1979; Mukhtar and Abu Naib, 1987). This study was conducted to assess the performance and yield of two soybean cultivars at two locations in the central rainlands of Sudan (11° 11′ – 12° 44′ N ; 34° – 35° E) under conditions of inadequate amount of rainfall suppplemented by irrigation at one site and completely under rainfed conditions at another site (Table 1). The objectives of this reseach were: (i) to determine if yields of the two cultivars planted on five dates would be affected by with–in row spacings, (ii) determine whether irrigation and plant spacing treatments could be combined to increase yields, and (iii) determine the optimum date of sowing both cultivars.

Table 1

Rainfall (mm) at Abu Naam Reseach Farm and Agadi Testing Site.

Site	Abu–Naama			Agadi		
Year / Month	1977	1978	1979	1977	1978	1979
July	68	135	92	144	113	128
August	296	108	82	237	244	163
September	66	83	152	98	213	75
October	10	23	66	6	36	36
Total	440	349	393	485	606	402

MATERIALS AND METHODS

Two soybean cultivars, Semmes with broad leaflets and maturity group VII, and Davis, with narrow leaflets and maturity group VI according to the American classification were grown over a 3 year period 1977–1979 each at 4 intra–row spacing of 2–5, 10, 15 and 30 cm. and over 5 sowing dates in factorial combinations in a randomised block design replicated 4 times. The experiment was conducted at two sites in the central rainlands of Sudan under supplementary irrigation at one site and completely rainfed at the other. The soils of the central rainlands of Sudan were described by Bunting and Lea (1962), as non–saline and have up to 70% montmorillonitic clay of pH 8.5–9 and the climate of these lands is tropical, continental and seasonally arid. Under supplementary irrigation at Abu Naama, the first sowing date was 15 June whereas at Agadi under rainfed conditions, the first sowing date was 30 June. At both sites subsequent sowing dates followed at 15 days interval until 15 August at Abu Naama and 30 August at Agadi. Inter–row spacing was kept constant at 60 cm. Plot size was 5 X 5 m. and the effective harvested area for grain yield was 3 X 3.5 m. A basic nitrogen dose of 43 kg/ha N was split applied into two equal halves, one at sowing and one at flowering. Seeds were dressed with a fungicide–insecticide chemical (Aldrex–T) of 25% Aldrin and 50% Thiram active ingredients 72 h prior to sowing at the rate of 3 g of chemical/1 kg of seeds. Sowing was on a flat seedbed under both systems of production. The plots were overseeded and thinned by hand 15 – 18 days later to the desired intra–row spacing after emergence. This method of obtaining the desired plant population provided consistent plant spacings (Boerma, 1977; Ramseur *et al.*, 1984). No inoculant is used and the soil is free of *Rhizobium* bacteria specific for soybeans (see Mukhtar and Abu Naib, 1987). All plots were made free of weeds throughout each growing season. Blister beetle (*Epicauta acthiops* Latr.) was the main insect pest, controlled mainly by hand picking and killing as well as frequent spraying by Thimul (35%) and Dimethoate (32%) mixture at the rate of 2.16 and 0.79 lb active ingredients per ha. for the two insecticides respectively. Symptoms of bacterial pustule was observed on variety Semmes but was not serious. Supplementary irrigation was used at Abu Naama every 14 days.

Ten plants chosen at random from the effective harvested area were used for measuring plant height and height of the first pod from soil surface. Plant height was recorded at maturity from the ground to the tip of the stem. The same ten plants were used for recording the number of pods per plant and then harvested and threshed individually using sticks to record number of seeds per plant. One thousand–seed weight was calculated from the same plants and grain yields were determined at 7% moisture. Stages of soybean development as described by Fehr and Caviness (1977) were followed. Data was subjected to analysis of variance (F test) to test significance due to differences between treatment means (Leclerg, *et al.*, 1962; Little, 1981).

Table 2

The effect of location and sowing date on day length and number of days from sowing to first flowering (RI) and to maturity (R7) of two soybean cultivars under two different systems of production in the central rainlands of Sudan (Data average of three years).

Location & System	Planting date	Day length		Days to flowering		Days to maturity	
		hr.	min.	Semmes	Davis	Semmes	Davis
	June 15	12	55	48 *2/87	33 18/7	120	100–109
Abu–Naama	June 30	12	53	50 14/8	33 2/8	113	95–103
Irrigated	July 15	12	49	44 28/8	32 16/8	114	105
Latitude 12°44′	July 30	12	40	43 11/9	33 1/9	103	93
	August 15	12	33	42 28/9	30 15/9	96	92
Agadi	June 30	12	53	46 15/8	31 31/7	100–110	90–95
Rainfed	July 15	12	51	47 1/9	28 12/8	95–100	80–85
Latidute 11°51′	July 30	12	47	41 10/9	27 26/8	90	79
	August 15	12	31	40 24/9	28 12/9	85	80

* Exact date to beginning flowering.

RESULTS

Rainfall

As shown by Table 1 there is considerable variability in the amount and distribution of rainfall between and within season at each site. However, total precipetation at Agadi is appreciably greater than that at Abu Nama.

Effect of location and sowing date on days to flowering and maturity

The data presented by Table 2 shows that both cultivars, Semmes and Davis responded to delayed sowing dates by reduction in number of days to flowering and maturity from sowing. The reduction in number of days to flowering from sowing for cultivar Semmes at both sites was 7–8 days whereas Davis recorded only 3 days reduction. For number of days from sowing to maturity the reduction in number of days in response to delayed sowings by Semmes at both sites was 24–25 days whereas for Davis it was 15–17 days. Despite the fact that the reduction in number of days to flowering and maturity was greater for Semmes than for Davis, yet at both sites Semmes flowered, at least, 10–12 days later than Davis. The growing season for both cultivars was longer under irrigated conditions ($P < 0.05$) at Abu Naama than under rainfed conditions at Agadi by about 10–20 days. It was observed that the narrowest intra–row spacing of 2–5 cm. hastened maturity of both cultivars under irrigated conditions by 4–6 days in the first sowing date crop. However, this effect was gradually masked by delayed sowings.

Table 3

Means of plant height (cm) of soybeans (measured at maturity) grown under two different systems of production at two sites in Sudan as affected by cultivar, sowing date and intra–row spacing.

Year	1977		1978		1979	
Location and system	Abu–Naama	Agadi	Abu–Naama	Agadi	Abu–Naama	Agadi
Effect of cultivar	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Semmes	*29.8	27.9	40.8	32.8	41.6	36.1
Davis	21.3	21.8	25.4	18.9	26.1	24.6
S.E.	0.32	0.40	0.56	0.28	0.42	0.40
Sowing date						
15 June	+28.6	–	34.8	–	37.0	–
30 June	27.6	27.2	35.6	22.9	36.1	32.6
15 July	24.8	25.5	34.2	29.3	33.7	32.5
30 July	23.3	26.5	29.3	24.9	36.9	30.3
15 August	23.9	20.4	31.5	26.3	25.7	25.9
S.E.	0.51	0.57	0.90	0.39	0.67	0.56
Intra–row spacing(cm)						
2–5	–26.9	28.0	37.8	30.2	37.0	36.1
10	26.4	25.8	33.5	25.8	33.7	29.5
15	24.5	23.6	31.5	24.3	32.7	29.1
30	24.4	22.2	29.6	23.1	32.1	26.8
S.E.	0.46	0.57	0.80	0.39	0.60	0.56

(*) Average over the dates + spacing; (+) Average over two cultivars + spacing; (–) average over two cultivars + sowing dates.

Vegetative growth

In 1978 and 1979 a significant (P = 0.01) interaction of planting date X cultivar X irrigation was measured. Semmes, the later flowering, was always taller than Davis by 12 cm. at both sites. Both cultivars produced shorter plants under rainfed conditions at Agadi (Table 3). Delayed sowing and wider intra–row spacings produced significantly shorter plants at both sites. The height of first pod from the ground was significantly greater for Semmes compared to Davis. However, delayed sowings and closer intra–row spacings produced significantly increased height of first pod from the ground (Table 4).

Table 4

Means of height of first pod from the ground (cm) of soybeans under two different systems of production at two sites in Sudan as affected by cultivar, sowing date and intra–row spacing.

Year	1978		1979	
Location and system	**Abu–Naama**	**Agadi**	**Abu–Naama**	**Agadi**
Effect of cultivar	**Irrigated**	**Rainfed**	**Irrigated**	**Rainfed**
Semmes	8.9	8.0	9.5	9.6
Davis	5.5	5.7	6.5	6.5
S.E.	0.26	0.08	0.11	0.09
Sowing date				
15 June	7.3	–	7.7	–
30 June	7.5	6.4	7.5	7.3
15 July	7.1	6.9	9.2	7.4
30 July	6.4	6.9	8.7	9.2
15 August	7.6	7.1	7.0	8.2
S.E.	0.37	0.11	0.17	0.13
Intrra–row spacing (cm)				
2 – 5	8.9	8.0	8.5	10.2
10	7.0	6.7	8.1	7.9
15	6.7	6.3	7.7	7.3
30	6.2	6.3	7.7	6.7
S.E.	0.41	0.11	0.15	0.13

Components of yield

i. Number of pods per plant

Semmes had a greater number of pods ($P = 0.05$) per plant under both systems compared to Davis. Wider intra–row spacing increased number of pods per plant at Abu Naama, whereas at Agadi under rainfed conditions, effect was erratic. Delayed sowing ($P < 0.05$) produced significant reduction in number of pods per plant under both systems of production (Table 5). On the whole Semmes has 5 more pods than Davis.

Table 5

Means of number of pods of soybeans grown under two different systems of production at two sites in Sudan as affected by cultivar, sowing date and intra–row spacing.

Year	1977		1978		1979	
Location and System	Abu–Naama Irrigated	Agadi Rainfed	Abu–Naama Irrigated	Agadi Rainfed	Abu–Naama Irrigated	Agadi Rainfed
Effect of Cultivar						
Semmes	42	24	45	28	37	42
Davis	36	22	39	21	34	36
S.E.	0.6	0.3	1.1	0.3	1.1	1.3
Sowing Date						
15 June	41	–	43	–	47	–
30 June	41	26	48	26	51	55
15 July	43	26	39	25	32	43
30 July	35	16	42	25	26	34
15 August	34	10	37	24	21	24
S.E.	1.0	0.4	1.7	0.4	1.7	1.9
Intra–row spacing (cm)						
2–5	36	24	35	25	32	27
10	41	24	42	25	34	35
15	39	23	43	25	36	40
30	39	20	48	25	41	54
S.E.	0.8	0.4	1.5	0.4	1.5	1.9

ii. Number of seeds per plant

Delayed sowings produced significant reduction in number of seeds under both systems. Wider intra–row spacing increased number of seeds per plant

significantly at Abu Naama under supplementary irrigation (P = 0.05) but under rainfed conditions an erratic effect was yielded (Table 6). On the whole Semmes has 7.5 seeds more than Davis.

Table 6

Means of seeds per plant of soybeans grown under two different systems of production at two sites in Sudan as affected by cultivar, sowing date and intra–row spacing.

Year	1977		1978		1979	
Location and System	Abu–Naama Irrigated	Agadi Rainfed	Abu–Naama Irrigated	Agadi Rainfed	Abu–Naama Irrigated	Agadi Rainfed
Effect of Cultivar						
Semmes	90	52	84	81	78	79
Davis	80	48	83	63	68	77
S.E.	1.2	0.8	1.5	0.3	2.0	2.3
Sowing Date						
15 June	90	–	93	–	90	–
30 June	88	57	91	73	108	116
15 July	95	59	84	73	69	90
30 July	78	35	80	71	54	62
15 August	73	–	71	72	45	45
S.E.	2.0	1.0	2.5	0.4	3.2	3.3
Intra–row spacing (cm)						
2–5	82	53	78	73	66	53
10	87	52	86	73	70	73
15	85	50	85	72	76	81
30	86	46	86	72	81	105
S.E.	1.7	1.1	2.3	0.4	2.9	3.3

iii. 1000–Seed weight

Cultivar Semmes had a significantly (P = 0.01) larger 1000–seed weight at both sites compared to Davis, however, delayed sowings significantly reduced this parameter. Intra–row spacing had no effect on 1000–seed weight under both systems of production (Table 7).

Table 7

Means of 1000-grain weight (g) of soybeans grown under two different systems of production at two sites in Sudan as affected by cultivar, sowing date seed intra-row spacing.

Year	1977		1978		1979	
Location and System	Abu-Naama Irrigated	Agadi Rainfed	Abu-Naama Irrigated	Agadi Rainfed	Abu-Naama Irrigated	Agadi Rainfed
Effect of Cultivar						
Semmes	109.2	72.1	121.4	113.0	119.6	116.8
Davis	104.1	83.0	115.4	110.7	107.6	109.7
S.E.	1.42	0.18	0.84	0.61	1.64	0.86
Sowing Date						
15 June	114.2	–	116.5	–	131.6	–
30 June	117.2	87.0	118.1	127.8	129.0	125.5
15 July	107.3	87.0	118.4	117.9	114.0	116.6
30 July	99.0	58.0	120.8	105.1	111.0	110.5
15 August	96.0	00.0	118.2	96.6	82.5	100.4
S.E.	2.25	2.23	1.34	0.86	2.59	1.21
Intra-row spacing (cm)						
2-5	105.2	86.0	116.9	111.1	112.3	110.7
10	105.8	81.0	116.3	111.9	119.9	113.2
15	108.5	83.0	118.9	112.8	115.7	114.5
30	107.2	85.0	121.5	111.6	106.6	114.7
S.E.	2.01	2.58	1.19	0.86	2.31	1.21

Biological Yield

The data (Table 8) show that cultivar Semmes was superior to Davis under rainfed conditions at Agadi in early sowings (30 June – 15 July) whereas Davis was superior to Semmes in late sowings under the same conditions. Under supplementary irrigation at Abu Naama, Semmes was superior to Davis up to 30 July. Overall cultivar Semmes produced more total dry matter than Davis at both sites. Wider intra-row spacing significantly reduced biological yield under both systems of production ($P < 0.05$) (Table 9). Under irrigated conditions at Abu Naama cultivar Semmes produced larger biological yield at all intra-row spacings compared to Davis. However, these differences were not very clear under rainfed conditions at Agadi.

Table 8

The effect of cultivar sowing date interaction on biological yield (t/ha) of soybean grown under two different systems of production at two sites in Sudan.

Location & System	Year	1977			1978			1979		
	Cultivar	Semmes	Davis	Mean	Semmes	Davis	Mean	Semmes	Davis	Mean
	Sowing date		±0.121			±0.152			±0.144	
Abu Naama	* 15 June	3.42	3.16	3.29	3.99	3.78	3.88	3.73	3.11	3.42
Irrigated	30 June	2.31	1.82	2.06	4.04	2.85	3.45	2.78	3.15	2.96
	15 July	2.02	0.75	1.38	3.36	3.04	3.20	2.69	1.96	2.32
	30 July	1.46	0.55	1.00	2.10	2.24	2.17	2.94	2.50	2.72
	15 Aug.	1.03	0.55	0.79	2.17	2.56	2.36	0.43	0.51	0.47
	Mean	2.05	1.36	1.70	3.13	2.89	3.01	2.51	2.24	2.38
	S.E.	0.052	0.052	0.085	0.068	0.068	0.107	0.064	0.064	0.102
	Sowing date		±0.80			±0.138			±0.134	
Agadi	15 June	–	–	–	–	–	–	–	–	–
Rainfed	30 June	1.00	1.14	1.07	2.46	1.45	1.95	3.44	2.74	3.09
	15 July	1.34	1.07	1.20	2.30	2.21	2.26	2.54	2.05	2.30
	30 July	0.41	0.96	0.69	1.69	1.45	1.57	1.70	1.75	1.73
	15 Aug.	0.09	0.26	0.17	1.77	1.84	1.80	0.61	0.84	0.73
	Mean	0.71	0.86	0.78	2.05	1.74	1.90	2.07	1.85	1.78
	S.E.	0.040	0.040	0.057	0.074	0.074	0.100	0.067	0.067	0.095

* In this table and in tables 10 and 12 no yield was obtained for 15 June sowing date.

Table 9

The effects of cultivar X intra–row spacing interaction on biological yield (t/ha) of soybean grown under two different systems of production at two sites in Sudan.

Location & System	Year	1977			1978			1979		
	Cultivar	Semmes	Davis	Mean	Semmes	Davis	Mean	Semms	Davis	Mean
	Intra–row spacing (cm)	±0.109			NS			NS		
Abu Naama	2–5	2.77	1.87	2.32	3.73	3.79	3.76	2.87	2.67	2.77
Irrigated	10	2.09	1.48	1.78	3.46	3.16	3.31	2.76	2.37	2.57
	15	1.63	1.28	1.46	2.78	2.68	2.77	2.40	2.22	2.31
	30	1.71	0.83	1.27	2.47	1.94	2.21	2.02	1.71	1.87
	Mean	2.05	1.36	1.71	3.13	2.89	3.00	2.51	2.24	2.38
	S.E.	0.052	0.052	0.080	0.068	0.068	0.140	0.064	0.064	0.091
	Intra–row spacing(cm)	±0.080			±0.138				NS	
Agadi	2–5	1.14	1.49	1.32	3.17	2.39	2.78	2.73	2.27	2.50
Rainfed	10	0.80	0.94	0.87	2.35	2.26	2.30	2.05	2.15	2.10
	15	0.66	0.63	0.65	1.70	1.62	1.66	1.99	1.84	1.91
	30	0.24	0.36	0.30	0.98	0.68	0.83	1.52	1.12	1.32
	Mean	0.71	0.86	0.79	2.05	1.74	1.89	2.07	1.85	1.96
	S.E.	0.040	0.040	0.057	0.074	0.074	0.100	0.067	0.067	0.133

Grain yield

The effect of cultivar, irrigation and planting date treament on seed yield were significant in all years. Without irrigation the yields are negligible except at first sowing in 1979 (Table 10 & 11). Cultivar Semmes (0.91 t/ha) was superior to Davis (0.80 t/ha) under irrigated conditions, whereas under rainfed conditions at Agadi (0.40 t/ha for Semmes and 0.47 t/ha for Davis) the reverse was true. Two most interesting points in these two tables are that although irrigation increased mean yield from 0.50 to 0.86 t/ha and gave acceptable yields at the first and second sowing dates, yet it did not affect the decline of yield with later sowings. Even more interesting is the observation that with irrigation and narrower intra–row spacings both cultivars gave larger yields at the earlier sowing dates.

Table 10

The effect of cultivar X sowing date interaction on grain yield (t/ha) of soybeans grown under two different systems of production at two sites in Sudan.

Location & System	Year	1977			1978			1979		
	Cultivar	Semmes	Davis	Mean	Semmes	Davis	Mean	Semmes	Davis	Mean
	Sowing date	*±0.053			±068			N S		
Abu Naama	15 June	1.40	1.27	1.34	1.31	1.00	1.16	1.45	1.26	1.36
Irrigated	30 June	0.74	0.80	0.77	1.34	1.09	1.22	1.14	1.13	1.14
	15 July	0.63	0.30	0.47	1.13	1.22	1.18	1.09	0.64	0.70
	30 July	0.53	0.20	0.36	0.85	0.81	0.83	0.77	0.93	1.01
	15 Aug.	0.36	0.20	0.28	0.85	0.93	0.89	0.15	0.17	0.16
	Mean	0.73	0.56	0.64	1.10	1.01	1.06	0.92	0.83	0.86
	S.E.	0.024	0.024	0.035	0.042	0.042	0.048	0.028	0.028	0.045
	Sowing date	N S			±0.060			±0.048		
Agadi	+15 June	–	–	–	–	–	–	–	–	–
Rainfed	30 June	0.25	0.46	0.34	0.85	0.55	0.70	1.08	1.15	1.11
	15 July	0.24	0.36	0.30	0.69	0.97	0.83	0.69	0.77	0.73
	30 July	0.13	0.30	0.22	0.41	0.58	0.50	0.47	0.54	0.51
	15 Aug.	+0.00	0.00	0.00	0.41	0.64	0.52	0.15	0.31	0.23
	Mean	0.16	0.28	0.22	0.59	0.68	0.64	0.60	0.69	0.50
	S.E.	0.017	0.017	0.021	0.03	0.03	0.042	0.042	0.042	0.034

* Significant at P = 0.05 NS Not Significant + No yield during 1977

Table 11

The effect of cultivar X spacing interaction on grain yield (t/ha) of soybeans grown under two different systems of production at two sites in Sudan.

Location & System	Year	1977			1978			1979		
	Cultivar	Semmes	Davis	Mean	Semmes	Davis	Mean	Semmes	Davis	Mean
	Intra-row spacing(cm)		±0.047			±0.061			NS	
Abu Naama	2-5	0.98	0.75	0.07	1.20	1.29	1.25	1.02	1.01	1.01
Irrigated	10	0.73	0.63	0.68	1.18	1.15	1.1	1.02	0.96	0.99
	15	0.60	0.55	.57	0.98	0.94	0.96	0.92	0.76	0.84
	30	0.61	0.29	0.45	1.03	0.67	0.85	0.72	0.59	0.65
	Mean	0.73	0.56	0.64	1.10	1.01	1.06	0.92	0.83	0.87
	S.E.	0.024	0.024	0.033	0.030	0.030	0.042	0.028	0.028	0.041
	Intra-row spacing(cm)		±0.035			NS			±0.048	
Agadi	2-5	0.37	0.62	0.49	0.92	0.98	0.95	0.76	0.86	0.81
Rainfed	10	0.20	0.44	0.32	0.68	0.88	0.78	0.61	0.87	0.74
	15	0.18	0.27	0.23	0.48	0.64	0.56	0.57	0.65	0.61
	30	0.10	0.16	0.13	0.28	0.25	0.27	0.45	0.38	0.42
	Mean	0.21	0.37	0.29	0.59	0.68	0.64	0.60	0.69	0.65
	S.E.	0.017	0.017	0.025	0.030	0.030	0.042	0.024	0.024	0.034

Harvest index

Delayed sowing under both systems of production reduced harvest index (grain yield: biological yield) of both cultivars drastically. Cultivar Davis was superior to Semmes under both systems of production, however, in 30 June sown crop at Abu Naama, under irrigated conditions, Semmes gave a bigger harvest index than Davis (Table 12).

Percentage protein and oil for Davis and Semmes under irrigated conditions at Abu Naama was 43.1, 22.2 and 41.6, 24.6% respectively.

Table 12

The effect of cultivar X sowing date interaction on harvest index of soybeans grown under two different systems of production at two sites in Sudan.

Location & System	Year	1977			1978			1979		
	Cultivar / Sowing date	Semmes	Davis	Mean	Semmes	Davis	Mean	Semmes	Davis	Mean
Abu Naama	15 June	0.409	0.402	0.406	0.328	0.265	0.296	0.389	0.405	0.397
Irrigated	30 June	0.320	0.440	0.380	0.332	0.382	0.357	0.410	0.359	0.385
	15 July	0.312	0.400	0.356	0.336	0.401	0.369	0.286	0.327	0.307
	30 July	0.363	0.364	0.364	0.404	0.362	0.383	0.371	0.372	0.372
	15 Aug.	0.350	0.364	0.357	0.392	0.363	0.378	0.349	0.333	0.341
	Mean	0.356	0.412	0.384	0.351	0.349	0.350	0.367	0.371	0.369
Agadi	15 June	–	–	–	–	–	–	–	–	–
Rainfed	30 June	0.250	0.404	0.327	0.346	0.379	0.363	0.314	0.420	0.367
	15 July	0.179	0.336	0.258	0.300	0.439	0.370	0.272	0.376	0.324
	30 July	0.317	0.313	0.315	0.243	0.400	0.322	0.276	0.309	0.293
	15 Aug.	0.000	0.000	0.000	0.232	0.348	0.290	0.246	0.369	0.308
	Mean	0.296	0.430	0.363	0.288	0.391	0.340	0.290	0.373	0.332

DISCUSSION

The effective growing season in the central rainlands of Sudan north of latitude 11° 51′ N is about 90 days. A cultivar like Semmes which requires 110 days to mature under rainfed conditions is regarded as late maturing whereas Davis which ripens in 90–95 days under the same conditions is regarded as early maturing. However, according to American maturing ratings, Semmes and Davis are in Maturity Group VII and VI respectively (Hinson Hartwig, 1982). The potential growing season for both cultivars is longer under supplementary irrigation than under rainfed conditions. Choice of sowing date influences the patterns of growth and development of crops, and in general is one of the means by which the seasonal distribution of leaf area index for a crop, and so its interception of the solar radiation can be manipulated (Monteith and Elston, 1983; Hughes, 1986).

Being a late maturing cultivar and yet irrigation did not offset effects of later sowings, Semmes outyielded Davis under irrigated conditions. Irrigation increased yields (when averaged across sowing dates) from the earlier plantings

– 30 June to 15 July – of Semmes by 0.44, 0.48 and 0.23 t/ha in 1977, 1978 and 1979 respectively and this was 0.06, 0.04 and 0.08 t/ha more than the increase achieved by irrigating the later plantings – 30 July to 15 August – of each respective year. Likewise, the irrigated earlier plantings of Davis in 1977, 1978 and 1979 produced increases in yield that were 0.14, 0.40 and 0.24 t/ha larger than increase achieved from irrigation of later plantings (0.05, 0.26 and 0.12 t/ha) of the respective years. Thus, in all of the five planting dates comparisons of the study, irrigation of 30 June and 15 July planted soybean resulted in larger yield increases than did irrigation of soybean planted in 30 July of mid August. Boerma and Ashley (1982) working with soybean sown in Georgia (U.S.A.), in late June or early July as opposed to those sown in late July or early August, measured a significant sowing date X irrigation treatment interaction in each year of their 3 years study. Heatherly and Elmore (1986) working with soybean planted in Stonville (U.S.A.), in mid May and around the beggining of June, measured a significant planting date X irrigation treatment interaction in each year of a 3 year study. These authors found that (as the finding in the present study) the yield response to supplemental irrigation was larger in the earlier of the two sowings.

Boerma and Ashley (1982) suggested that factors other than water, such as length of the vegetative and reproductive periods were limiting seed yield of their late plantings. This limiting factor might have occurred in the present study and resulted in substantial decrease of yield in later sowings at both locations with or without supplementary irrigation (Tables 10 & 11). When risk factors are taken into account, early establishment has clear practical advantages. In the present study later sowings have reduced yield, and the effect is partly explained in terms of the onset of cool winter conditions (November and beggining of December) resulting in (a) a relatively short growing season (photoperiodism), (b) a drop in the night temperature, and (c) probably a decreasing moisture availability under rainfed conditions. It has been recently recognized (Thomas and Raper, 1978; Seddigh and Jolliff, 1984) that the effect of warm night temperature (16–24°C on soybean yield) – rather than using only the photoperiodic response to the plant – is a potential criterion for developing new soybean cultivars. Night temperature is of major importance for growth and development of soybean as it affects both photoperiodic response and morphology of the crop (Seddigh and Jolliff, 1984). Constable and Rose (1988) indicated that although daylength changes the least at tropical latitudes, yet tropical soybean cultivars are highly sensitive to photoperiodism.

Few studies have been conducted which examine the combined effects of irrigation and plant spacing on soybean yields. Ramseur *et al.,* (1984) working with soybean planted at Simpson Experiment Station (U.S.A.) indicated that the responses of yield components to the intra–row spacing had no apparent pattern. Davis gave similar grain yields to Semmes at the narrowest intra–row spacing of 2 – 5 cm in this study. This is in accord with Hinson and Hartwig (1982) who stated that early maturing varities responded better than late maturing varities to high population densities. The early maturity of plants sown 2 – 5 cm apart as compared to those sown at wider intra–row spacings, is attributed to the rapid leaf senescence activated by overlapping of leaves in the narrowest intra–row spacing treatments. The difference between the two cultivars in light interception and penetration into the plant canopies is related to their leaf size and arrangement which resulted in different patterns of leaf senescence in the two cultivars. The growth and yield of crops are determined primarily by the amount of solar radiation intercepted by their canopies during the growing season (Monteith and Elston, 1983). Overall leaf senescence in cultivar Davis which has narrow leaflets is more or less uniform along the stem, whereas in variety Semmes which has broad leaflets, most of the leaf senescence concentrated on the lower and middle parts of the stem first and then proceeded upwards later.

There are differing reports as to whether yield increases are due to seed weight or due to seed number (Ramseur *et al.,* 1984; Heatherly and Elmore, 1986). In the present study there were increases in pod number and seed per pod for the irrigated treatments compared to the rainfed treatments. This result is consistent with the finding of Ramseur *et al.,* (1984) who indicated that increases in seed number under the irrigated treatments were due to increases in both pod number and seed per pod. Although 1000–seed weight of Semmes is larger than that of Davis under rainfed conditions, yet Davis produced more grain yield than Semmes. This indicates that seed weight has no effect on grain yield which is in agreement with the findings of Hartwigs and Edwards (1970). The reduction in number of pods and seeds per plant with delayed sowing is attributed to decreasing day lengths at both sites and to decreasing moisture availability with delayed sowings under rainfed conditions (Table 2). Since delayed sowings increased height of first pod on the stem from the ground which reduced space available for pod setting on the stem in this study, this could be one reason for decreasing number of pods per plant with delayed sowings. Plant

height in this study was increased by irrigation, closer intra–row spacing and early sowing dates. Irrigation promoted vigorous and more vegetative growth which led to increased plant height whereas closer intra–row spacing promoted competition between plants along the row which resulted in thinner and taller plants. Harvest index and biological yield are amongst the main plant traits that ultimately lead to a better understanding of seed yield in soybean (Salado–Navarro *et al.,* 1986).

In the present study the harvest index (ratio of grain yield to biological yield) of cultivar Davis was greater under rainfed conditions than under irrigated conditions whereas the reverse was true for cultivar Semmes. This might be due to the increase in days to flowering under irrigated conditions which promoted vegetative growth by cultivar Davis but not a similar increase in grain yield later. But for cultivar Semmes, the superiority of its genetic potential found an ideal environment under irrigation to express itself thus producing more grain yield and consequently giving a higher harvest index under irrigation than under rainfed conditions. Overall the harvest index of either cultivar under both systems of production could be an indicator of its suitability for production under certain conditions in either systems of production. This is in accord with Arnon (1972) who emphasized selection of varities with high grain:straw ratio for dry land agricultural production. The great difference in total dry matter and grain yield of both cultivars under irrigated conditions as compared to production levels under rainfed conditions, illustrate clearly the positive response of soybeans to irrigation. This is in total agreement with the findings of Beech *et al.,* (1979); Doss and Thurlow, (1974); Ramseur *et al.,* (1984) and Heatherly and Elmore, (1986).

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أثر الري ومواعيد الزراعة والمسافة بن الجور على نمو فول الصويا تحت ظروف زراعية جافة

أحمد محمد علي إسماعيل و فتحي محمد خليفه

إن الأبحاث في مجال زراعة فول الصويا في السودان مازالت محدودة ، لذلك قد أجريت تجارب حقلية في منطقة أبو نعامة وأجادي (الوسط الشرقي للسودان) لدراسة أثر الري ومواعيد الزراعة وكثافة النباتات على نمو وإنتاج فول الصويا .

تم زراعة طرزين من فول الصويا : سمز وديفز على مدى ثلاث سنوات في مزرعة أبو نعامة (مطر + ري) وفي مزرعة أجادي حيث كان المحصول يروي بماء المطر فقط وقد تم ذلك في خمسة مواعيد زراعة وأربعة مسافات بين الجور .

دلت النتائج على أن الطرز سمز كان متفوقاً في إنتاجه في أبو نعامة على ديفز ، بينما تفوق ديفز على سمز في أجادي ، كان للزراعة المتأخرة والمسافات الكبيرة بين الجور أثراً واضحاً في تدني الإنتاج في أبو نعامة وأجادي ، كما كان للري أثراً واضحاً في زيادة انتاج الطرزين في أبو نعامة بالمقارنة مع أجادي . ومن النتائج المتحصل عليها يتضح مدى التأثير الكبير لموعد الزراعة إلى المحصول ومكوناته ، وقد تبين أن أفضل موعد للزراعة الفترة من منتصف يونيو إلى منتصف يوليو .