DEFICIT IRRIGATION AT DIFFERENT GROWTH STAGES OF THE COMMON BEAN (*Phaseolus vulgaris* L., cv. IMBABELLO)

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ABSTRACT: To identify specific growth stages of the common bean crop at which the plant is less sensitive to water stress, in which irrigation could be omitted without significant decrease in final yield, two field experiments were conducted at "La Tola" University Experimental Station, Tumbaco, Pichincha, Ecuador, on a sandy loam soil (Typic Haplustoll). The climate is tempered and dry (mean air temperature 16°C and mean relative humidity 74%, during the cropping season) 123 and 109 mm of rainfall were recorded during the experimental cropping periods (July to October), of 1992 and 1994, respectively. The treatments consisted of combinations of 7 irrigation regimes including normal watering; full stress; (traditional management practice); single stress at vegetative stage; flowering; seed formation and ripening, and of 2 levels of applied N (20 and 80 kg/ha). These 14 treatment combinations were arranged and analysed in a split-plot design with 4 replications. The plot size was 33.6 m^2 (8 rows, 7 m long) with a plant population of 120,000 pl/ha. Irrigation treatments were started after uniform germination and crop establishment. Soil water content was monitored with a neutron probe down to 0.50 m depth, before and 24 h after each irrigation. The actual evapotranspiration of the crop was estimated by the water-balance technique. Field water efficiency and crop water use efficiency were calculated. Yield data showed that the treatments which had irrigation deficit had lower yield than those that had supplementary irrigation. The flowering stage was the most sensitive to water stress. Nitrogen fertilization significantly increased the number of pods and grain yield. Crop water use efficiency (kg/m^3) was the lowest with stress at the flowering period, and the yield response factor (Ky) was higher in treatments of full stress and stress at flowering. In relation to the traditional management practice adopted by farmers, only treatments of normal watering and stress at maturation had 13 and 10% higher crop water use efficiency, respectively.
Key Words: common bean, irrigation, water stress, water use efficiency

DEFICIÊNCIA DE ÁGUA EM DIFERENTES ESTÁDIOS DE DESENVOLVIMENTO DO FEIJOEIRO (*Phaseolus vulgaris* L., cv. IMBABELLO)

RESUMO: Com o objetivo de identificar estádios específicos de desenvolvimento do feijoeiro, nos quais a planta é menos sensível à deficiência de água e a irrigação poderia ser suprimida sem decréscimo significativo em produtividade, dois experimentos de campo foram conduzidos na Estação Experimental "La Tola", pertencente à Universidade Central de Equador, em Tumbaco, Pichincha, Equador. Os tratamentos consistiram de combinações de sete regimes de irrigação, incluindo a irrigação normal, deficiência completa, prática de manejo tradicional, deficiência no período vegetativo, deficiência na floração, deficiência na formação de vagens e deficiência no enchimento de grãos, e de dois níveis de fertilizante nitrogenado, 20 e 80 kg/ha. Essas quatorze combinações de tratamentos foram organizadas e analisadas segundo um delineamento estatístico de parcelas sub-divididas, com quatro repetições. As parcelas foram de 33,6 m^2 (8 linhas de 7 m de comprimento, com uma população de 120.000 pl/ha. Os tratamentos de irrigação iniciaram-se após a germinação uniforme e estabelecimento da cultura. O conteúdo de água do solo foi monitorada com sonda de nêutrons até a profundidade de 0,5 m, antes e 24 h após cada irrigação. A evapotranspiração atual da cultura foi estimada pelo balanço hídrico. Calculou-se as eficiências de uso de água no campo e pela cultura. Dados de produtividade mostram que os tratamentos que tiveram deficiências apresentaram menor produtividade em relação a tratamentos com irrigação complementar. O estádio do floresci-mento foi o mais sensível à deficiência de água. A fertilização com N aumentou significativamente o número de vagens por planta e a produção de sementes. A eficiência de uso de água pela cultura (kg/m^3) foi menor com deficiência na floração, e o fator de resposta à produtividade (kg) foi maior nos tratamentos de deficiência total e deficiência no florescimento. Considerando as práticas tradicionais de manejo utilizadas pelos agricultores, apenas os tratamentos de irrigação normal e de deficiência na maturação, tiveram uma eficiência de uso de água de 13 e 10% maior, respectivamente.
Descritores: feijão comum, irrigação, deficiência de água, eficiência de uso de água

INTRODUCTION

In Ecuador, the bean crop (*Phaseolus vulgaris* L.) is generally cultivated under rainfed conditions, in marginal lands in the semi-arid higlands (1800-3000m). Water stress is a very common problem during the growing period, exacerbated by the fact that the crop is planted in shallow soils with low nutrient and organic mater contents. The bean crop is grown during the part of the year when rainfall is expected, but alternate wet and dry periods of varying lengths affect the production potential. Common beans have a relatively shallow rooting depth, poor nodulation, require frequent irrigations (Miller & Gadner, 1972; Stansell & Smitle, 1980; Weaver *et al.*, 1984; Calvache & Garcia, 1987) and large supplies of N fertilizers (Westerman *et al.*, 1981; Calvache 1989; Castrillo *et al.*, 1990). The increasing demands for limited water supplies and the rising costs of nitrogenous fertilizers lead to a rational use of these resources without adversely affecting production.

Cell expansion is one of the first growth processes affected by water stress. As a consequence, plants under severe stress are generally stunted. Leaf area, one of the main components of above-ground biomass, is also reduced by drought, due to reduced leaf area expansion and premature senescence (Salisbury & Ross, 1992). This process acts as a survival tactic, reducing the rate of water use and delaying the onset of more severe stress, but is generally irreversible. However, given favorable conditions, plants with an indeterminate growth habit, like cowpeas and dry beans, may late compensate for this loss of leaf area by producing new leaves.

As observed by Castrillo *et al.*, (1990) water deficit can result in a sudden decrease in nitrate redutase activity and fluctuations in ammonium content. Protein content may show significant decrease under deficit, folowed by an increase with addition of water. Under moderate water deficit, an initial protein degradation can take place, followed by protein synthesis at the expense of accumulated reduced nytrogen; leaf protein is probably used as a source of reduced nitrogen for new protein synthesis.

Water requirements of the common bean has received very litle attention in Ecuador and therefore, the purpose of this study was to identify specific growth stages of the common bean crop at which the plant is less sensitive to water stress and irrigation can be omitted without a significant decrease an final yield, and also to determine how irrigation deficits can affect fertilizer use efficiency.

MATERIALS AND METHODS

Two Field experiments were carried out at "La Tola" Agricultural Experimental Station in Tumbaco, Pichincha, Ecuador, on a Typic Haplustoll soil sandy loam texture (16% clay; 0.8% organic matter and pH 6.8). Seven waterstress treatments were tested at different growth stages (E1- vegetative; E2- flowering; E3- Bean formation and E4- Ripening period), two levels of applied N-fertilizer (F_1- 20 and F_2- 80 kg/ha N) and two levels of irrigation: 1) Normal watering when real evapotranspiration was equal to the expected maximun (ETm); and 0) Deficit irrigation (aproximatly = 1/2 ETm).

These combinations resulted in 14 treatments shown in TABLE 1.

Physical and chemical characterization of the soil and neutron probe calibration (Greacen, 1981), were carried out before actual experimental work was iniciated. Bean seeds v. Imbabello were planted on July 3/1992 and July 2/1994. Plots of 33.6 m^2, 8 furrows of 7 m (2 seeds per 25 cm) were distributed in a split-plot design, with a plant population of 120,000/ha. Irrigation treatments started after uniform germination and crop establishment (Doorenbos & Kassan, 1979). Soil water content was measured with a neutron probe from 10 to 50 cm depth, before and 24 h after each irrigation, with measurements every 10 cm. Soil matric potential was monitored by installing tensiometers at 0.20m; 0.40 and 0.60 m, between plants in a crop row.

The actual evapotranspiration (ETa) of the crop was estimated by the water-balance technique and drainage or upward flow from ground water was calculated by Darcy equation. Field water efficiency ($Ef=kg/m^3$) and crop water use efficiency $Ec=kg/m^3$) were calculated dividing the actual grain yield (10% seed water content) y irrigation and by actual evapotranspiration (Eta), respectively (Doorenbos & Pruit, 1977; Hillel, 1990). Samples of 4 plants were collected at diferent growth stages and 50 plants at the time of final harvest, to determine dry matter and nitrogen content in leaf and stem, dry weight of pods harvested, number of pods and harvest index.

TABLE 1 - Treatment combinations.

		Growth Stage				
No.	Treatments	1	2	3	4	Description
1	F1 IR1	1	1	1	1	Normal watering
2	F1 IR2	0	0	0	0	deficit irrigation
3	F1 IR3	..	..	..	..	Traditional practice
4	F1 IR4	0	1	1	1	stress at vegetation
5	F1 IR5	1	0	1	1	Flowering
6	F1 IR6	1	1	0	1	Yield formation
7	F1 IR7	1	1	1	0	Ripening stages
8	F2 IR1	1	1	1	1	Normal watering
9	F2 IR2	0	0	0	0	deficit irrigation
10	F2 IR3	..	..	..	..	Traditional practice
11	F2 IR4	0	1	1	1	stress at vegetation
12	F2 IR5	1	0	1	1	Flowering
13	F2 IR6	1	1	0	1	Yield formation
14	F2 IR7	1	1	1	0	Ripening stages

TABLE 2 - Physical Analysis and Moisture Calibration Curve of the Soil (BD = bulk density; PD = particle density; A = calibration intercept; B = calibration slope).

DEPTH (cm)	SAND (%)	SILT (%)	CLAY (%)	BD g.cm3	PD g.cm3	Por. (%)	A	B
0-10	70	16	14	1.4	2.65	52.8	0.089	0.16
10-28	72	12	16	1.45	2.62	44.7	+0.009	0 .18
28-60	54	20	26	1.36	2.51	45.8	-0.05	0 .21

RESULTS AND DISCUSSION

The results of the physical analysis and the calibration of the neutron probe are shown in TABLE 2

TABLE 3 illustrates data of evapotranspiration calculated according to the modified Penman method and irrigation requirements for the treatment of normal watering (R1).

Deficit irrigation at different growth stages significantly influenced plants water evaporation and water balance (TABLES 4, 5, 6, 7, 8, 9, 10). Drainage or upward flow from ground water was practically insignificant and did not cause significant error in the estimate of actual evapotranspiration (Eta).

TABLE 11 show soil water storages down to the 0,50 m depth during the two experimental periods. It can be seen that water content increases after an irrigation or rain, depending on the treatment. Water storage in the treatment of full stress (IR2) was lower than in the treatment of normal watering (IR1). Generally water storage in all the treatments was higher than that of the treatment of full stress (IR2) in the stages in which irrigation was made, but lower than in the treatment IR1 which received irrigation during the entire cycle.

From the yield data presented in TABLES 12 and 13 it can be concluded that treatments which had irrigation deficit have lower yields than those that had supplementary rrigation (1% probability). The flowering stage was the most sensitive to water stress. The treatment of stress at flowering stage (IR5) had the same result as the one which had water stress during the whole growing cycle (IR2), in the two experimental years (1992 and 1994). Comparing the results of fertiized treatments it can be seen that there are significant differences (1% probability) between the two fertilization levels used in the two experimental years (1992 and 1994). The interaction between irrigation and fertilization was only statistically different in the second experimental year (1994). The highest value was obtained in the treatment IR4F2. It can also be seen that the lower yields correspond to treatments IR5F2>IR5F1>IR2F2>R2F1 which is the reflex of the fact that common bean requires frequent irrigations and soil matric potential of -10 to -30 kPa for optimum growth (Miller & Gadner, 1972; Stansell & Smitle, 1980).

TABLE 3 - Days after sowing (DAS), degrees-day (GD), crop coefficient (Kc), evapotranspiration (Eta), effective rainfall and irrigation needs for experimental conditions.

Mês	DAS	$GD_{(5°C)}$	Kc	ETc	Chuva efetiva mm/década	Irrigação
Jul	10	106	0.35	16.0	0.2	15.7
Jul	20	212	0.35	16.1	0.0	16.1
Jul	30	318	0.38	18.0	0.5	17.5
Aug	40	424	0.54	26.8	1.0	25.8
Aug	50	530	0.80	41.8	1.5	40.3
Aug	60	636	1.04	52.2	4.5	47.7
Setembro	70	742	1.15	54.8	7.5	47.4
Setembro	80	848	1.15	52.9	10.4	42.5
Setembro	90	954	1.11	50.0	15.3	34.7
Outubro	100	1060	1.02	44.7	22.1	22.5
Outubro	110	1166	0.90	38.8	28.0	10.8
Outubro	120	1272	0.79	33.4	22.2	11.3
Novembro	130	1278	0.68	28.2	4.5	13.3
TOTAL	130	1378		473.7	117.6	356.1

A highly significant difference was found in seed yield as an effect of water treatments. Results presented in TABLE 13 show that the seed weigth of teatments IR2 and IR3 were the lowest. In common beans a loss of reproductive organs can occur even under the most favorable conditions; this loss can be of different magnitudes in the same cultivar, depending on the environmental conditions. In the present study the quantity of reproductive organs shed during the development of the crop under the different water treatments was not measured, however a major shed of flowers and young pods was observed in the water stress treatments (IR2, IR3, IR5). Without exception, the yield components were dimished by the stress treatments, and this decrease was more severe in IR6 with the reduction of numbers of pods per plant and weigth of 100 seeds.

Aspinal & Paleg (1981) have enphatized that the organ wich is growing most rapidly at the time of the stress is the one most afected. For example, in the vegetive stage, the leaves and in rippening stage, the seeds. This relationship can actually lead to an increased harvest index (HI) under water stress because of strong reduction in vegetative growth. The treatment IR4 had HI of 0.59 , that is 18% over that of the control IR1. The nitrogen fertilization increased significantly the HI. Treatments F2 (80 kg N/ha) had HI 24% higer than of plants.F1, in accordance to Albrech *et al.*, (1984) and Hedge & Srinivas, (1990).

All stress treatments evaluated in this study reduced seed yield, however, as indicated, the highest reduction was found when the stress was imposed at the beginning of grain formation. This reduction in yield was due mainly to the reduction in the number of pods per plant. In this research, a small reduction in the number of seeds per pot and seed weigth was observed in treatments IR2 and IR7. The differences in yield among irrigation treatments could be attributed to the significant variations in the number of pods per plant. The improvement in yield with N fertilization was due to a significant increase in the number of pods per plants. Common bean being a poor nodulator, responds to the aplication of N.

TABLE 4 - Water balance for irrigation regime 1 (IIII). (DAS = days after sowing); A = water storage down to 0.50 m; VA = change of water storage; P = rainfall; I = irrigation; D = drainage or upward flow; ETa = actual evapotranspiration; ET ac = accumulated evapotranspiration.

DAS	A	VA	P	I	D	ETa	ET ac
	(mm)	......	......	(mm/day)	......	......	(mm)
14	139.9			30.0		1.6	22.4
17	134.6	-5.3	1.5	0.0	-0.07	2.2	29.1
26	134.5	-0.1	0.0	25.0	-0.19	2.8	54.0
34	134.3	-0.2	0.0	25.0	-0.28	3.1	79.0
40	139.6	5.3	2.3	25.0	-0.80	3.5	100.2
47	142.7	3.1	4.5	25.0	-2.00	3.5	124.6
53	140.1	-2.6	0.0	25.0	-1.97	4.3	150.2
60	134.4	-5.6	0.0	22.0	-1.30	3.8	176.5
68	122.5	-12.0	0.0	30.0	-0.28	5.2	218.2
75	113.1	-9.4	0.3	26.0	-0.02	5.1	253.9
82	129.7	16.6	30.7	26.0	0.01	5.7	294.0
88	111.4	-18.3	13.3	0.0	0.01	5.3	325.6
96	131.4	20.0	37.5	13.0	0.01	3.8	356.1
102	114.1	-17.3	1.6	0.0	0.01	3.1	375.0
109	107.4	-6.8	0.0	18.0	0.00	3.5	399.7
115	117.0	9.6	6.0	26.0	0.00	3.7	422.1
122	126.4	9.4	13.2	22.0	0.01	3.7	447.9
TOTAL		-13.5	110.9	338	-6.86		

To compare the two experiments, TABLE 14 presents the final data for the variables: field water use efficiency (Ef), crop water use efficiency (Ec) yield response factor (Ky) and relative yield response factor. Treatments IR1 and IR7 have more Ec than the other due to the higher productivity. Treatment IR2 has higher Ef due to the small quantity of applied irrigation water during the crop cycle. The Ky is higher in treatments IR2 and IR5, and lower in treatments IR1 and IR7.

Water use of common bean was markedly influenced by the irrigation treatments. There was a decline in ETa with decreasing water content in the soil. This could be due to a combination of both, reduced surface soil evaporation with lower irrigation frequency and greater plant water deficits with low soil matric potentials. Water use efficiency, however, was maximun with deficit irrigation at the vegetative stage (IR4) and declined with irrigation frequency.

TABLE 5 - Water balance for irrigation regime 2 (0000). (DAS = days after sowing); A = water storage down to 0.50 m; VA = change of water storage; P = rainfall; I = irrigation; D = drainage or upward flow; ETa = actual evapotranspiration; ET ac = accumulated evapotranspiration.

DAS	A	VA	P	I	D	ETa	ET ac
	(mm)	(mm/day)					(mm)
14	133.9			30.0		1.6	22.4
17	131.0	-2.9	1.5	0.0	-0.25	1.4	26.6
26	130.9	-0.1	0.0	10.0	-0.56	1.1	36.1
34	121.2	-9.8	0.0	0.0	-0.43	1.2	45.4
40	116.3	-4.8	2.3	0.0	-0.20	1.2	52.3
47	116.8	0.5	4.5	13.0	-0.12	2.4	69.2
53	110.8	-6.0	0.0	0.0	-0.02	1.0	75.2
60	103.9	-6.9	0.0	0.0	0.03	1.0	82.2
68	104.3	0.4	0.0	15.0	0.01	1.8	96.8
75	97.1	-7.2	0.3	0.0	0.00	1.1	104.3
82	111.2	14.1	30.7	0.0	0.00	2.4	120.9
88	106.0	-5.2	4.0	0.0	0.00	1.5	130.1
96	101.1	-5.0	11.3	0.0	0.00	2.0	146.3
102	96.6	-4.5	0.5	0.0	0.00	0.8	151.3
109	96.8	0.2	0.0	14.0	0.00	2.0	165.1
115	95.2	-1.6	1.8	0.0	0.00	0.6	168.5
122	96.2	1.0	4.0	0.0	0.00	0.4	171.5
TOTAL		-37.8	60.9	82.0	-1.52		

TABLE 6 - Water balance for irrigation regime 3 (RT). (DAS = days after sowing); A = water storage down to 0.50 m; VA = change of water storage; P = rainfall; I = irrigation; D = drainage or upward flow; ETa = actual evapotranspiration; ET ac = accumulated evapotranspiration.

DAS	A	VA	P	I	D	ETa	ET ac
	(mm)	......	......	(mm/day)	......	......	(mm)
14	135.8			30.0		1.6	22.4
17	129.7	-6.1	1.5	0.0	-0.02	2.5	30.0
26	127.3	-2.4	0.0	13.0	-0.04	1.7	45.4
34	124.1	-3.2	0.0	13.0	-0.03	2.0	61.5
40	123.7	-0.3	2.3	13.0	-0.02	2.6	77.2
47	122.1	-1.7	4.5	13.0	-0.02	2.7	96.3
53	117.0	-5.1	0.0	13.0	-0.01	3.0	114.4
60	114.1	-2.9	0.0	11.0	0.00	2.0	128.3
68	104.2	-9.9	0.0	14.0	0.00	3.0	152.2
75	101.4	-2.8	0.3	15.0	0.00	2.6	170.2
82	113.2	11.8	30.7	13.0	0.00	4.6	202.2
88	106.8	-6.4	13.3	0.0	0.00	3.3	221.9
96	119.1	12.3	37.5	7.0	0.00	4.0	254.0
102	108.6	-10.6	1.6	0.0	0.00	2.0	266.2
109	101.7	-6.9	0.0	5.0	0.00	1.7	278.0
115	106.2	4.5	6.0	13.0	0.00	2.4	292.6
122	110.3	4.1	13.2	12.0	0.00	3.0	313.7
TOTAL		-25.5	110.9	185.0	-0.14		

TABLE 7 - Water balance for irrigation regime 4 (0III). (DAS = days after sowing); A = water storage down to 0.50 m; VA = change of water storage; P = rainfall; I = irrigation; D = drainage or upward flow; ETa = actual evapotranspiration; ET ac = accumulated evapotranspiration.

DAS	A	VA	P	I	D	ETa	ET ac
	(mm)	...........(mm/day)...........					(mm)
14	136.4			30.0		1.6	22.4
17	130.7	-5.7	1.5	0.0	-0.01	2.4	29.6
26	127.4	-3.3	0.0	0.0	-0.04	0.4	32.8
34	121.4	-6.0	0.0	0.0	-0.02	0.7	38.8
40	117.2	-4.2	2.3	0.0	0.00	1.1	45.3
47	113.5	-3.7	4.5	6.0	0.03	2.0	59.6
53	115.1	1.6	0.0	25.0	0.02	3.9	83.0
60	117.4	2.3	0.0	22.0	0.03	2.8	102.7
68	112.6	-4.8	0.0	30.0	0.01	4.3	137.5
75	107.8	-4.8	0.3	26.0	0.00	4.4	168.6
82	124.7	16.9	30.7	26.0	0.00	5.7	208.4
88	112.9	-11.8	13.3	0.0	0.00	4.2	233.5
96	129.7	16.8	37.5	13.0	0.00	4.2	267.2
102	115.9	-13.8	1.6	0.0	0.00	2.6	282.6
109	109.7	-6.2	0.0	18.0	0.00	3.5	306.8
115	116.6	6.9	6.0	26.0	0.00	4.2	331.9
122	128.3	11.7	13.2	22.0	0.00	3.4	355.4
TOTAL		-8.1	110.9	244.0	0.02		

TABLE 8 - Water balance for irrigation regime 5 (I0II). (DAS = days after sowing); A = water storage down to 0.50 m; VA = change of water storage; P = rainfall; I = irrigation; D = drainage or upward flow; ETa = actual evapotranspiration; ET ac = accumulated evapotranspiration.

DAS	A	VA	P	I	D	ETa	ET ac
	(mm)	.....	.....	..... (mm/day)	.....	.....	(mm)
14	137.2			30.0		1.6	22.4
17	130.7	-6.5	1.5	0.0	-0.15	2.6	30.3
26	129.0	-1.8	0.0	25.0	-0.35	2.9	56.7
34	129.8	0.8	0.0	25.0	-0.23	3.0	80.7
40	131.4	1.6	2.3	25.0	-0.10	4.3	106.2
47	132.4	1.0	4.5	25.0	-0.18	4.0	134.6
53	118.2	-14.2	0.0	0.0	-0.23	2.3	148.5
60	109.4	-8.8	0.0	0.0	-0.07	1.2	157.3
68	104.0	-5.4	0.0	0.0	-0.01	0.7	162.7
75	99.7	-4.3	0.3	0.0	0.00	0.7	167.3
82	118.8	19.1	30.7	25.0	0.00	5.2	203.9
88	110.1	-8.7	13.3	0.0	0.00	3.7	225.8
96	129.1	19.0	37.5	13.0	0.00	3.9	257.3
102	113.4	-15.7	1.6	0.0	0.00	2.9	274.6
109	106.2	-7.3	0.0	18.0	0.00	3.6	299.9
115	115.6	9.4	6.0	26.0	0.00	3.8	322.5
122	124.9	9.3	13.2	22.0	0.00	3.7	348.4
TOTAL		-12.4	110.9	234.0	-1.30		

TABLE 9 - Water balance for irrigation regime 6 (II0I). (DAS = days after sowing); A = water storage down to 0.50 m; VA = change of water storage; P = rainfall; I = irrigation; D = drainage or upward flow; Eta = actual evapotranspiration; Et ac = accumulated evapotrasnpiration.

DAS	A	VA	P	I	D	ET	ET ac
			(mm)			(mm/day)	(mm)
14	132.0			30.0		1.6	22.4
17	129.5	-2.5	1.5	0.0	-0.02	1.3	26.4
26	125.8	-3.6	0.0	25.0	-0.02	3.2	55.0
34	122.5	-3.4	0.0	25.0	-0.01	3.5	83.4
40	128.5	6.1	2.3	25.0	-0.01	3.5	104.6
47	130.8	2.3	4.5	25.0	-0.02	3.9	131.8
53	123.0	-7.8	0.0	25.0	-0.01	5.5	164.6
60	119.7	-3.3	0.0	22.0	-0.01	3.6	189.9
68	112.9	-6.8	0.0	30.0	0.00	4.6	226.7
75	100.1	-12.9	0.3	15.0	0.00	4.0	254.8
82	106.3	6.2	30.7	0.0	0.00	3.5	279.3
88	103.5	-2.8	4.0	0.0	0.00	1.1	286.1
96	102.4	-1.2	11.3	0.0	0.00	1.6	298.5
102	98.0	-4.4	0.5	0.0	0.00	0.8	303.4
109	103.0	5.0	0.0	30.0	0.00	3.6	328.4
115	110.9	7.9	6.0	26.0	0.00	4.0	352.5
122	125.4	14.5	13.2	22.0	0.00	3.0	373.2
TOTAL		-6.6	74.3	300.0	-0.09		

TABLE 10 - Water balance for irrigation regime 7 (III0). (DAS = days after sowing); A = water storage down to 0.50 m; VA = change of water storage; P = rainfall; I = irrigation; D = drainage or upward flow; ETa = actual evapotranspiration; ET ac = accumulated evapotranspiration.

DAS	A	VA	P	I	D	ETa	ET ac
	(mm)	.....	.....	(mm/day)	.....	.....	(mm)
14	135.3			30.0		1.6	22.4
17	130.7	-4.6	1.5	0.0	-0.12	2.0	28.4
26	129.3	-1.4	0.0	25.0	-0.21	2.9	54.5
34	126.8	-2.6	0.0	25.0	-0.01	3.4	82.1
40	142.3	15.6	2.3	25.0	-0.03	2.0	93.8
47	138.8	-3.5	4.5	25.0	-0.40	4.7	126.4
53	128.0	-10.8	0.0	25.0	-0.39	5.9	161.8
60	126.1	-1.9	0.0	22.0	-0.34	3.4	185.4
68	116.3	-9.9	0.0	30.0	-0.08	5.0	225.2
75	110.5	-5.7	0.3	26.0	-0.09	4.6	257.1
82	125.5	15.0	30.7	26.0	0.01	6.0	298.8
88	110.2	-15.3	13.3	0.0	0.01	4.8	327.4
96	124.6	14.4	37.5	13.0	0.01	4.5	363.5
102	108.1	-16.5	0.5	0.0	0.00	2.8	380.5
109	98.1	-10.1	0.0	0.0	0.00	1.4	390.6
115	94.7	-3.4	1.8	0.0	0.00	0.9	395.8
122	96.1	1.4	4.0	0.0	0.00	0.4	398.4
TOTAL		-39.2	96.4	272.0	-1.63		

TABLE 11 - Water storage (mm) 0 to 0.50 m depth DAS= days after sowing.

DAS	IR1	IR2	IR3	IR4	IR5	IR6	IR7
1992							
20	95	96	104	89	95	97	99
25	90	97	97	86	88	89	88
32	93	95	98	87	90	93	92
39	112	97	106	106	103	98	101
43	118	89	114	101	110	101	105
46	128	97	121	100	122	110	120
53	114	90	104	95	106	105	104
60	108	90	93	90	95	100	99
67	112	92	90	93	93	96	101
74	121	97	104	108	103	101	121
81	109	92	94	98	99	92	107
88	122	94	104	105	106	92	116
95	115	87	99	100	107	87	107
102	150	103	147	151	142	135	112
109	119	102	114	128	115	112	108
1994							
17	135	131	130	131	131	129	131
26	135	131	127	127	129	126	129
34	134	121	124	121	130	122	127
40	140	116	124	117	131	128	142
47	143	117	122	113	132	130	139
53	140	111	117	115	118	123	128
60	144	103	114	117	109	120	126
68	132	104	104	113	104	113	116
75	123	97	101	108	100	100	111
82	140	117	113	125	119	106	126
88	121	124	107	113	110	110	110
96	141	101	119	130	129	102	125
102	124	97	109	116	113	98	108
109	117	97	102	110	106	103	98
115	127	95	106	116	116	111	95
122	136	96	110	128	126	125	96

TABLE 12 - Yield components as a function of treatments (1992).

FACTORS	Yield (Kg/ha)	N° of pods/plant	Harvest index
Irrigation	(**)	(**)	(**)
I1	2627 a	15 ab+	0.55 b
I2	1164 c	10 c	0.52 b
I3	2264 ab	14 abc	0.59 ab
I4	2462 ab	14 abc	0.65 a
I5	1775 bc	11 bc	0.55 b
I6	2146 abc	13 abc	0.56 b
I7	2453 ab	17 a	0.55 b
Fertilization	(**)	(**)	(**)
F1	1994 b	13 b	0.51 b
F2	2260 a	14 a	0.62 a
Interactions	(ns)	(ns)	(*)
I1F1	2240	14 bcde	0.44 ef
I1F2	3015	17 ab	0.66 ab
I2F1	1267	10 ef	0.39 f
I2F2	1060	9 f	0.66 ab
I3F1	2153	14 bcde	0.58 bc
I3F2	2376	14 bcde	0.60 bc
I4F1	2294	13 bcde	0.56 bc
I4F2	2631	15 abcd	0.74 a
I5F1	1754	11 ef	0.45 e
I5F2	1796	11 ef	0.64 abc
I6F1	1969	12 cde	0.57 bc
I6F2	2324	14 bcde	0.55 c
I7F1	2158	16 abcd	0.57 bc
I7F2	2620	19 a	0.54 d
CV (%)	15	12	17

ns = non significant - F test
* = significant at 5% level - F test
** = highly significant at 5% level - F test
+ = averages followed by different letter in the same column differ statistically at $p < 0,05$

TABLE 13 - Yield components as a function of treatments (1994).

Factors		Yield	N° of pods/plant	N° of grains/pod	Mass of 100 grains (g)	Harvest index
Irrigation		**	**	**	**	**
R1		2974.30 a	23.08 a	4.43 a	51.72 ab	0.50 b
R2		1285.58 d	15.58 d	4.32 a	49.04 c	0.47 b
R3		2494.83 ab	18.18 c	4.40 a	49.81 bc	0.54 ab
R4		2990.78 a	22.60 a	4.47 a	53.85 a	0.59 a
R5		2302.20 bc	19.01 bc	4.41 a	51.69 ab	0.50 b
R6		1910.17 c	20.48 b	4.41 a	51.37 bc	0.51 b
R7		2301.06 bc	23.50 a	3.87 b	44.76 d	0.51 b
Fertilization		**	**	**	NS	**
F1		2088.77 b	19.33 b	4.27 b	50.47	0.46 b
F2		2556.62 a	21.36 a	4.39 a	50.17	0.57 a
Interactions		*	*	NS	MS	**
R1	F1	2711.22 bcd	22.10 bc	4.45	52.33	0.40 ef
R1	F2	3237.30 ab	24.05 ab	4.40	51.10	0.60 ab
R2	F1	1058.35 h	15.48 g	4.12	49.65	0.35 f
R2	F2	1512.80 gh	15.68 g	4.53	48.42	0.60 abc
R3	F1	2090.55 ef	16.83 fg	4.28	50.18	0.53 bcd
R3	F2	2899.11 abc	19.53 cdef	4.51	49.44	0.55 bcd
R4	F1	2677.28 cd	21.53 bcde	4.47	52.88	0.51 bcd
R4	F2	3304.28 a	23.68 ab	4.48	54.82	0.68 a
R5	F1	2085.40 f	18.78 ef	4.40	51.50	0.41 ef
R5	F2	2518.98 cde	19.25 def	4.43	51.88	0.59 abcd
R6	F1	1734.20 fg	18.88 ef	4.33	51.68	0.52 bcd
R6	F2	2086.15 ef	22.08 bc	4.50	51.06	0.50 cde
R7	F1	2264.36 def	21.75 bcd	3.89	45.05	0.52 bcd
R7	F2	2337.76 de	25.25 a	3.86	44.48	0.49 de
	CV(%)	8.5	4.62	3.98	2.99	8.49

ns = non significant - F test
* = significant at 5% level - F test
** = highly significant at 5% level - F test
\+ = averages followed by different letter in the same column differ statistically at $p < 0.05$

TABLE 14 - Field water efficiency (Ef = Kg/m^3), Actual Evapotranspira-tion (Eta = mm), Crop Water Use Efficiency (Ec = kg/m^3), Relative Evaporation Deficit (Ky), at fertilization level F1.

Treat	Ef	ETa	Ec	1-ETa/ETm	1-Ya/Ym	KY	Ky relative
				1992			
I1	0.60	355	0.63	0.00	0.00	-	-
I2	0.61	222	0.57	0.37	0.43	1.16	1.00
I3	0.72	314	0.69	0.12	0.04	0.34	0.29
I4	0.71	316	0.73	0.11	0.00	0.00	0.00
I5	0.56	321	0.55	0.10	0.22	2.27	1.95
I6	0.64	309	0.64	0.13	0.12	0.93	0.80
I7	0.94	340	0.63	0.04	0.04	0.87	0.75
				1994			
I1	0.60	448	0.61	0.00	0.00	-	-
I2	0.74	172	0.62	0.62	0.61	0.99	1.00
I3	0.71	314	0.67	0.30	0.23	0.76	0.77
I4	0.75	356	0.75	0.21	0.01	0.06	0.06
I5	0.60	348	0.60	0.22	0.23	1.04	1.05
I6	0.46	373	0.46	0.17	0.36	2.16	2.18
I7	0.61	398	0.57	0.11	0.16	1.49	1.51

Relation to the traditional practice adopted by farmers of the region, only treatments IR1 and IR7 had 13 and 10% higher crop water use efficiency. The relative evaporation deficit (Ky) was lowest at the IR4 and higher at IR5 treatments.

CONCLUSIONS

Crop water use efficiency was the lowest at the flowering period and the yield reponse factor (Ky) was higher in treatment IR2 and IR 5. The flowering stage was the most sensitive to moisture stress. Nitrogen fertilization significantly increased the number of pods and grain yield.

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