Chickpea Agronomy

Progress Report No.2

1986/87

ICRISAT

Crop Physiology Unit
Legumes Program

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1991

This report has been prepared for the purpose of sharing preliminary experimental information with scientists interested in chickpea improvement. However, it is not an official publication of ICRISAT and should not be cited.

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C O N T E N T S

1. INTRODUCTION

This season marked the completion of a series of multidisciplinary studies on effects of solarization on chickpea. The experiments included multilocation testing of solarization effects, evaluation of residual effects of solarization, interactions with Rhizobium and effects on chickpea growth in saline areas. Pulse Agronomy was responsible for the management of these field experiments although scientists from different disciplines were involved in various measurements on the experiments.

The stationing of Dr. N.P. Saxena at Gwalior allowed the conduct of detailed studies on adaptation of chickpea to the Gwalior environment, and facilitated monitoring of the cold tolerance study at Hisar. An important development in this season was the identification of non-nodulating mutants among established chickpea cultivars and the testing of their suitability for use as non-fixing controls in quantification of nitrogen fixation.

This season also saw further development of greenhouse pot tests for use in diagnosis of nutrient disorders in chickpea and evaluation of small field plot tests to determine on-site adequacy of phosphorus, nitrogen and Rhizobium. Screening of differences in moisture response among chickpea genotypes utilizing a line-source sprinkler technique was continued and finalized in this season. In collaboration with the chickpea breeders, advanced genotypes were evaluated on large plots with and without irrigation and a large demonstration block of ICCC 37 was grown.

This report documents the most important data obtained in the 1986/87 experimental program on chickpea together with some brief interpretive remarks. Additional experimentation was also carried out in Pulse Agronomy, by the GOJ Special Project, but this will be reported separately in a terminal report for this Project.

For the experiments reported here, any additional details of experimental procedures, trial layouts and further ancillary data can be obtained from the respective Experiment Proposals, seasonal field books and base data files maintained in Pulse Agronomy.

The comments and suggestions of readers are welcome.

Commonly used symbols

SE = standard error of mean.
* = difference significant at $P<0.05$.
** = difference significant at $P<0.01$.
*** = difference significant at $P<0.001$.
NS = not significant.
DAS = days after sowing

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3. METEOROLOGICAL AND SOILS DATA

I. Meteorological Data

Weekly data for the period June 1986 to May 1987 are given for ICRISAT Center, Gwalior and Hisar in Figures 3.1, 3.2 and 3.3, respectively. We also give these data in numeric form in Tables 3, 1, 3.2 and 3.3, for those who may wish to utilize these data more precisely (request from Dr R.J. Summerfield, University of Reading, UK). These data have been compiled by the Agroclimatology Section of Resources Management Program - Agronomy.

At ICRISAT Center (18°N, 78°E; 542 m asl; 782 mm average annual rainfall), rainy season rainfall was below average but rainfall during the chickpea growing period was about normal.

At Gwalior (26°N, 78°E; 212 m asl; 899 mm average annual rainfall), rainy season rainfall was well below average and only in January 1987 was monthly rainfall above average. Temperatures during the chickpea growing period did not deviate markedly from the long-term averages.

At Hisar (29°N, 75°E; 221 m asl; 450 mm average annual rainfall), rainy season rainfall was a little below average. There was no rain in Nov-Dec 1987 but above-average rain in Jan-Feb 1987. December and January maximum and minimum temperatures were generally below normal.

II. Soils Data

Details of chemical analysis of soil samples taken from the experimental sites during 1986 are given in Table 3.4. Details of sampling and analysis techniques are given in Chickpea Agronomy Progress Report No.1 (1985/86) pp. 5-7. These analyses were conducted by the Soil Fertility Laboratory of the Resources Management Program, which we gratefully acknowledge.

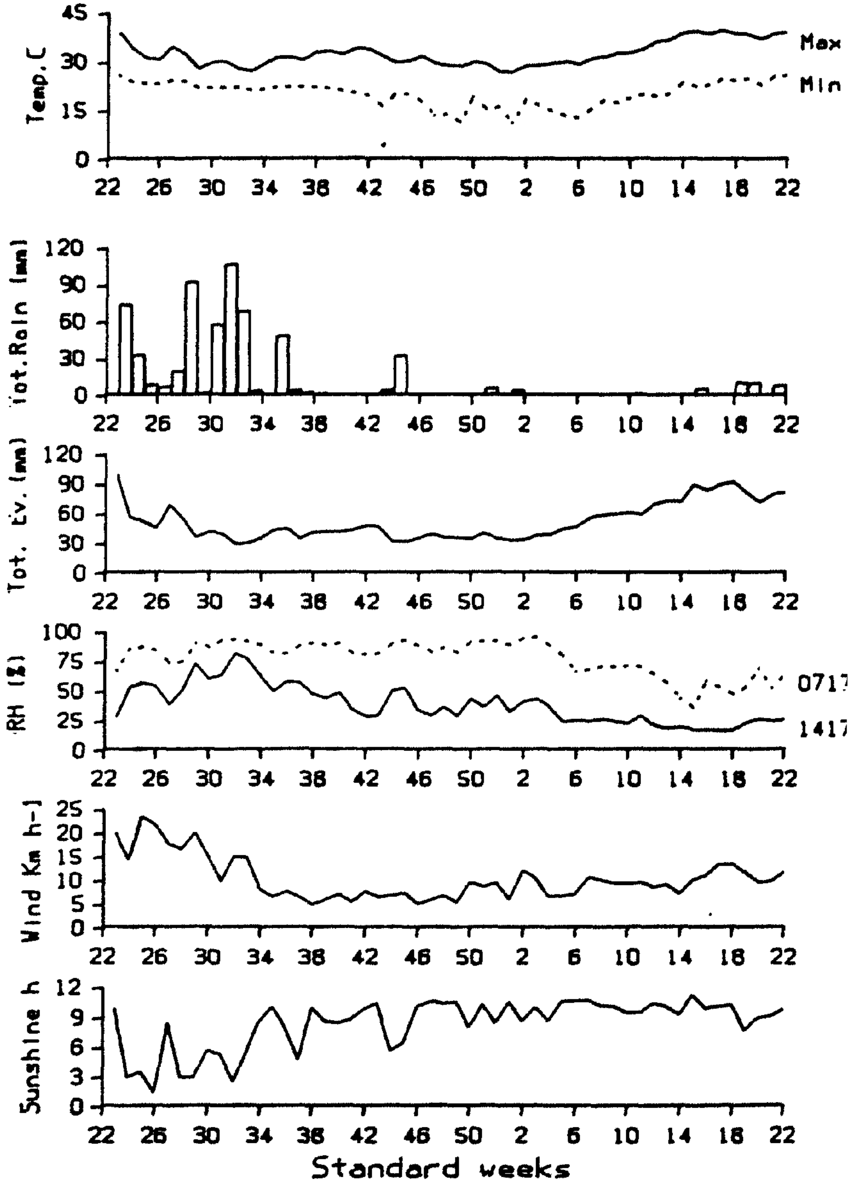

Fig. 3.1. Meteorological data for ICRISAT Center, Patancheru, during 1986/87.

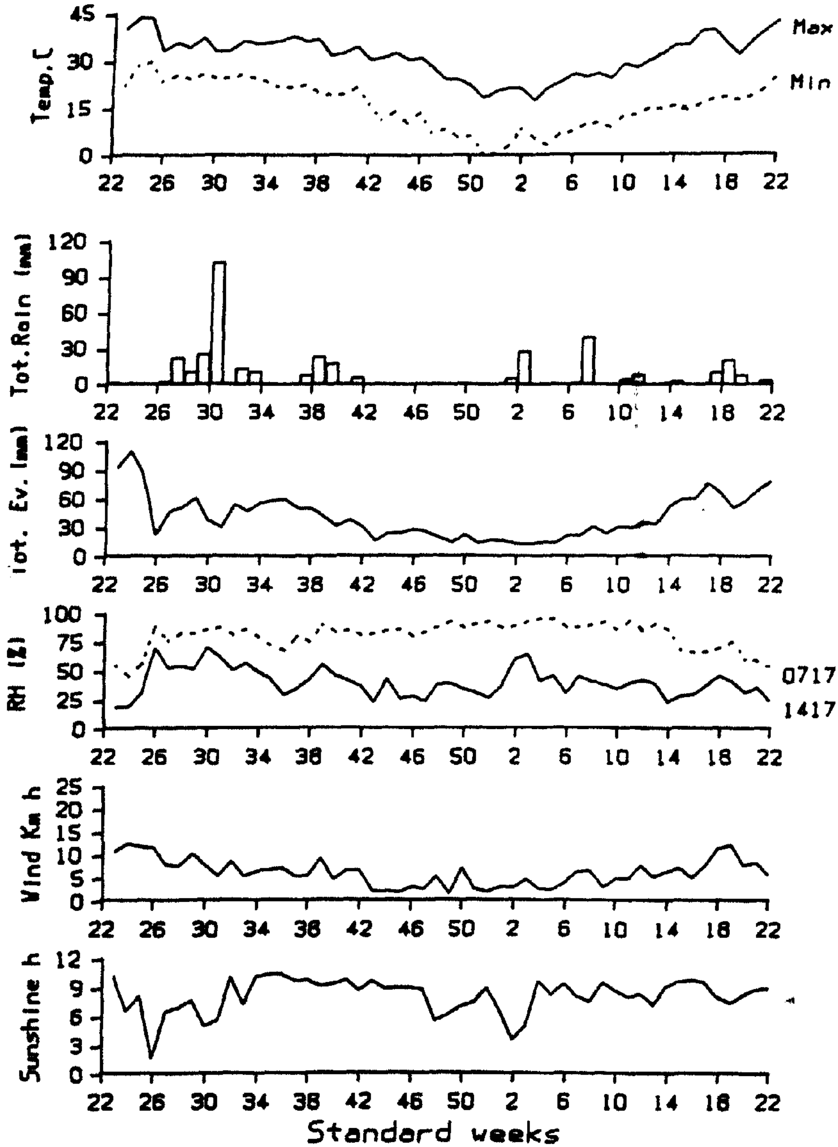

Fig. 3.2. Meteorological data for ICRISAT Cooperative Sub-center, Hisar, during 1986/87.

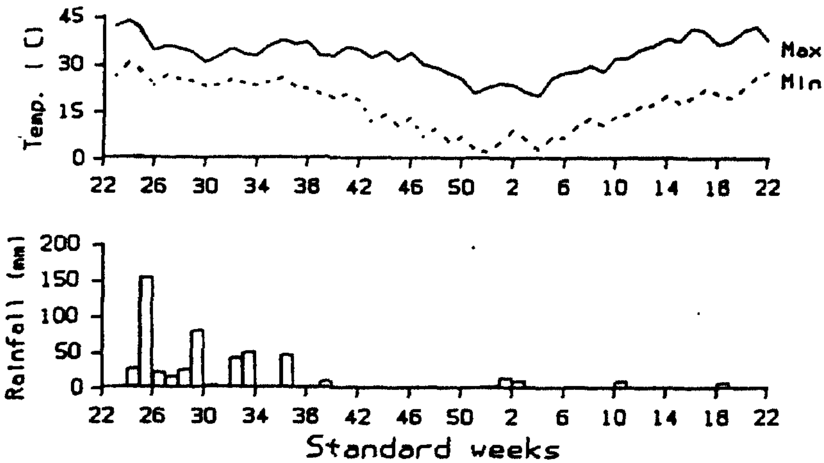

Fig. 3.3. Temperature and rainfall data for ICRISAT Cooperative Sub-center, Gwalior, during 1986/87.

Table 3.1. Meteorological data for ICRISAT center during 1986/87.

Year	Std week	Rain (mm)	Evap (mm)	Temperature max	Temperature min	RH07 (%)	RH14 (%)	Wind kmph	Sunshine hr	Solarad mj/m**2/d
1986	23	0.0	98.6	38.6	25.5	67.4	29.1	19.9	9.8	23.9
	24	73.8	54.5	33.7	23.5	85.9	54.0	14.3	2.9	14.4
	25	33.3	50.7	30.8	23.2	87.3	57.3	23.5	3.4	14.5
	26	8.9	43.8	30.3	23.0	83.9	53.0	21.7	1.3	10.9
	27	7.0	68.9	34.2	24.2	73.3	38.1	17.6	8.6	20.5
	28	20.1	53.7	31.9	23.9	74.4	50.4	16.5	2.8	14.8
	29	93.6	35.8	27.9	21.9	90.1	72.9	20.1	2.9	10.9
	30	2.3	41.1	29.6	21.7	86.6	59.4	15.3	5.7	15.9
	31	58.0	38.3	29.9	21.9	93.0	63.6	9.6	5.2	16.1
	32	107.8	28.2	27.5	21.9	93.7	81.6	15.2	2.4	13.2
	33	69.2	29.7	27.0	21.3	91.4	76.0	14.7	5.4	14.2
	34	4.1	34.0	29.1	21.4	88.7	61.4	8.0	8.7	19.2
	35	0.0	43.1	31.4	22.3	81.7	49.1	6.4	10.1	22.8
	36	49.2	44.4	31.4	22.3	81.4	57.7	7.5	7.9	19.2
	37	4.4	33.2	30.3	22.3	88.4	58.7	6.4	4.6	17.7
	38	2.3	40.8	33.0	22.2	90.4	46.7	4.8	10.0	21.7
	39	1.4	41.2	33.2	21.8	89.3	43.6	5.9	8.5	19.9
	40	0.0	40.5	32.1	21.2	90.6	48.6	6.9	8.4	17.7
	41	0.0	42.1	34.1	20.3	81.6	33.6	5.2	8.8	18.3
	42	0.0	47.8	33.6	19.6	81.1	28.1	7.6	9.9	18.5
	43	0.0	45.0	31.6	16.3	81.7	28.9	6.4	10.4	19.4
	44	4.6	30.3	29.6	20.2	90.0	51.7	6.7	5.5	13.6
	45	32.6	30.3	29.8	20.0	92.6	52.4	7.4	6.5	14.4
	46	0.0	34.2	31.7	17.8	87.7	32.7	4.9	10.2	17.4
	47	0.0	38.6	29.3	13.5	83.1	28.7	5.8	10.6	18.1
	48	0.0	35.2	28.5	13.9	87.3	36.7	6.8	10.4	16.7
	49	0.0	35.2	28.3	11.4	82.3	27.7	5.2	10.5	16.7
	50	0.3	33.0	29.9	19.4	91.3	43.3	9.6	7.9	13.3
	51	0.0	39.8	29.2	15.3	92.0	35.1	8.7	10.3	17.5
	52	6.0	33.3	26.7	16.1	92.3	45.8	9.4	8.4	14.2
1987	1	0.0	32.2	27.0	11.1	88.4	31.7	5.9	10.5	17.8
	2	4.4	32.8	28.6	18.7	94.4	41.0	12.1	8.5	15.3
	3	0.0	37.2	28.8	16.5	95.4	43.0	10.2	10.0	17.7
	4	0.0	38.2	29.4	14.8	87.6	36.0	6.5	8.6	16.6
	5	0.0	44.6	29.9	13.5	79.4	23.3	6.7	10.6	18.8
	6	0.0	45.5	29.0	12.8	66.0	24.9	6.9	10.7	18.8
	7	0.0	55.3	30.7	15.5	67.6	23.4	10.6	10.7	19.0
	8	0.0	59.0	31.4	18.4	70.9	25.7	9.9	10.1	18.6
	9	0.0	59.3	32.4	17.3	70.1	23.4	9.3	10.0	18.8
	10	0.0	60.3	32.6	19.0	71.4	22.4	9.1	9.3	18.2
	11	2.0	58.0	33.6	20.0	70.1	29.1	9.6	9.4	20.6
	12	0.0	70.1	36.0	19.5	64.6	20.3	8.5	10.4	22.7
	13	0.0	72.4	36.5	20.2	56.7	18.1	9.2	10.0	21.8
	14	0.0	71.7	38.8	23.7	43.4	19.9	7.0	9.2	20.6
	15	0.0	89.5	39.1	22.5	35.7	16.4	10.1	11.2	25.3
	16	6.0	83.2	38.6	22.9	59.1	16.4	11.0	9.9	22.7
	17	0.0	89.8	39.6	24.6	53.1	16.0	13.4	10.1	23.2
	18	0.0	92.0	38.3	24.1	46.9	16.0	13.3	10.2	23.6
	19	10.8	80.8	38.0	24.9	53.7	22.9	11.5	7.6	19.9
	20	10.4	70.6	36.7	22.7	69.1	25.9	9.5	9.0	22.8
	21	0.0	79.1	38.6	25.6	52.0	23.9	9.8	9.1	21.5
	22	8.6	81.0	38.8	25.8	63.3	25.0	11.7	9.8	23.0

Table 3.2. Meteorological data for Hisar subcenter during 1986/87

Year	Std week	Rain (mm)	Temperature C Max	Min	RH07 (%)	RH14 (%)	Wind kmph	Sunshine hr	Evap (mm)
1986	23	2.2	40.3	22.4	55	19	11	10.2	13.4
	24	0.0	44.0	28.7	45	19	13	6.5	15.7
	25	0.0	43.6	29.7	56	32	12	8.2	12.3
	26	124.7	32.8	23.1	89	70	12	1.6	9.5
	27	2.6	35.6	25.5	76	52	8	6.6	6.7
	28	22.5	34.1	24.5	83	53	7	6.9	7.3
	29	10.8	37.7	25.9	83	51	10	7.8	8.9
	30	26.2	33.1	24.8	87	71	8	4.9	5.3
	31	102.9	33.1	24.9	88	62	5	5.7	6.5
	32	0.0	36.4	26.0	81	50	9	10.1	7.7
	33	13.3	35.5	24.6	87	57	5	7.3	6.7
	34	10.4	35.9	23.5	80	48	6	10.2	8.0
	35	0.0	36.6	21.9	72	43	7	10.4	8.4
	36	0.0	37.9	21.7	69	29	7	10.4	8.5
	37	0.0	36.4	22.7	80	21	5	9.7	7.2
	38	8.2	37.1	20.4	76	43	5	9.8	7.3
	39	23.8	31.6	19.4	91	56	9	9.2	5.9
	40	18.0	32.7	19.6	85	46	4	9.3	4.5
	41	0.0	34.8	21.9	86	42	7	9.9	5.5
	42	6.6	30.4	16.5	82	37	7	8.7	6.4
	43	0.0	31.2	11.6	83	23	2	9.6	7.3
	44	0.0	32.6	14.4	85	43	2	8.9	3.4
	45	0.0	30.4	10.4	87	26	2	9.1	3.4
	46	0.0	30.9	13.9	80	29	3	9.0	4.0
	47	0.0	27.7	6.9	84	23	2	8.7	3.5
	48	0.0	24.3	8.7	89	39	5	5.5	2.7
	49	0.0	24.0	6.0	93	40	1	6.2	2.1
	50	0.0	22.2	6.6	88	34	7	7.2	3.3
	51	0.0	18.1	1.1	91	31	2	7.6	2.0
	52	0.0	20.4	0.9	94	27	2	8.9	2.1
1987	1	0.0	21.5	3.7	88	39	3	6.4	2.2
	2	4.8	21.2	9.0	90	61	3	3.6	1.7
	3	28.3	17.2	5.5	94	65	5	5.0	1.7
	4	0.0	21.4	3.6	96	41	2	9.7	2.1
	5	0.0	23.4	7.0	95	46	2	8.2	1.9
	6	0.0	25.8	7.8	89	30	4	9.4	3.1
	7	2.2	24.5	9.7	89	46	6	8.1	3.0
	8	40.0	25.7	10.6	90	41	7	7.6	4.5
	9	0.0	24.2	8.8	93	38	3	9.6	3.3
	10	0.0	28.8	12.3	86	34	5	8.7	4.5
	11	4.5	27.4	12.8	94	40	5	8.1	4.1
	12	8.3	29.9	14.9	86	42	8	8.5	5.1
	13	0.1	31.8	14.6	91	39	5	7.3	4.8
	14	1.8	34.6	15.5	87	23	6	9.2	7.5
	15	2.6	34.6	14.1	67	29	7	9.6	8.6
	16	0.0	38.7	16.1	67	30	5	9.9	8.6
	17	0.0	39.2	17.7	67	38	8	9.6	11.0
	18	10.3	34.6	18.1	70	46	12	7.9	9.3
	19	20.5	31.2	17.3	75	40	12	7.3	7.2
	20	7.8	35.9	18.5	60	31	8	8.3	8.4
	21	0.0	39.3	20.8	59	36	8	8.8	10.1
	22	4.0	42.2	25.2	54	24	6	8.9	11.2

Table 3.3. Meteorological data for Gwalior subcenter during 1986/87

Year	Std week	Temperature C Max	Min	RH (%)	Rain (mm)
1986	23	42.1	26.2	38.4	0.0
	24	43.7	30.7	36.7	0.0
	25	40.5	27.3	48.0	27.7
	26	34.1	23.4	70.6	154.4
	27	35.5	26.2	65.9	22.1
	28	34.4	24.8	66.9	16.3
	29	33.2	24.2	66.1	26.6
	30	30.1	22.7	82.9	80.5
	31	32.2	23.5	83.6	4.6
	32	34.6	24.7	75.6	3.1
	33	32.9	23.7	80.3	43.2
	34	32.3	23.2	74.1	51.0
	35	35.5	24.3	64.6	0.0
	36	36.9	25.3	55.6	0.0
	37	35.9	22.8	73.9	47.7
	38	36.8	22.1	61.9	0.0
	39	32.0	20.2	81.1	9.1
	40	32.3	19.3	78.9	9.9
	41	35.2	20.6	74.3	0.0
	42	34.3	18.6	68.7	1.5
	43	31.8	11.6	52.7	0.0
	44	34.1	14.1	50.1	0.0
	45	30.7	10.5	52.4	0.0
	46	33.5	12.9	45.9	0.0
	47	29.5	7.2	61.9	0.0
	48	28.4	9.5	76.6	0.0
	49	26.9	5.6	71.9	0.0
	50	25.2	6.5	76.6	0.0
	51	20.6	3.7	70.3	0.0
	52	22.3	2.3	68.1	0.0
1987	1	23.7	5.2	56.0	4.8
	2	23.3	9.0	87.9	15.5
	3	20.7	6.2	87.7	11.2
	4	22.4	3.0	78.7	0.0
	5	25.5	6.8	82.4	0.0
	6	27.3	6.6	73.3	0.0
	7	27.3	10.4	72.6	2.0
	8	29.7	12.9	70.3	29.2
	9	27.5	10.7	65.6	0.0
	10	32.1	13.5	57.3	0.0
	11	32.0	14.2	53.7	10.7
	12	34.8	16.6	43.1	0.0
	13	35.9	17.1	43.1	0.0
	14	38.1	19.9	28.1	0.0
	15	37.2	17.7	23.7	0.0
	16	41.5	19.5	23.7	0.0
	17	40.4	22.0	22.9	0.0
	18	36.1	20.7	46.9	31.8
	19	37.0	19.2	51.6	8.3
	20	40.5	22.5	31.1	0.0
	21	42.4	25.7	27.0	0.0
	22	43.5	27.4	30.9	0.0

Table 3.4. Soil analysis of fields used for chickpea agronomy experiments trials in 1986/87. Means and standard errors given

Soil type and field	Sampling depth (cm)	pH	EC (dS/m)	Organic carbon (%)	Avail. P (mg/kg soil)	Exchange. K (mg/kg soil)	NH_4^+-N (mg/kg soil)	NO_3^--N (mg/kg soil)	Total N (mg/kg soil)
Vertisol									
BP 6A (n=4)	0-15	8.2 ±0.03	0.25 ±0.006	0.49 ±0.017	5.87 ±0.966	-	2.0 ±0.14	6.7 ± 1.04	607 ±23.9
BP 7A (n=4)	0-15	8.3 ±0.02	0.27 ±0.009	0.45 ±0.007	4.56 ±0.359	-	1.9 ±0.14	11.8 ± 1.97	567 ± 3.2
BP 7B (n=4)	0-15	8.3 ±0.02	0.25 ±0.005	0.45 ±0.004	4.19 ±0.387	-	1.6 ±0.39	8.2 ± 0.57	557 ±12.7
BP 8C (n=4)	0-15	8.4 ±0.06	0.24 ±0.016	0.43 ±0.014	3.87 ±0.21	-	1.8 ±0.66	7.8 ± 1.42	557 ±17.2
Entisol									
Coordinated trial (n=4)	0-15	8.0 ±0.10	0.48 ±0.096	0.51 ±0.012	17.50 ±1.27	373 ±7.6	0.9 ±0.10	35.9 ±12.75	603 ±11.9
	15-30	8.0 ±0.06	0.35 ±0.046	0.24 ±0.025	1.94 ±0.71	171 ±6.4	0.6 ±0.18	9.4 ± 2.60	470 ±19.6
	30-60	7.9 ±0.05	0.35 ±0.033	0.15 ±0.019	0.81 ±0.31	143 ±7.8	0.9 ±0.80	5.5 ± 1.34	411 ± 9.8

4. C-110(85)IC Climatic adaptation in chickpea

4.1. Objectives

a) To define the limits to adaptation of commercially growth chickpea varieties posed by moisture, light and temperature.

b) To identify genotypes with characters capable of extending these limits of adaptation.

c) To determine canopy structure in chickpea most efficient in utilizing incident light and available soil moisture for carbon fixation and transfer to seeds.

d) To identify genotypes which can maximize harvest index in environments conducive to good vegetative growth.

4.2 PA 86/38 Development of chickpea genotypes tolerant to low temperatures during flowering and pod set (NPS, JK)[1]

Introduction

At Hisar and other similar cooler environments in northern India most of the present day chickpea cultivars flower during Dec and Jan but pods fail to develop then. The failure in pod set is because of low night temperature, particularly when it falls below 8° C. This results in a period of ineffective podding which is considered undesirable from the point of view of realising high yields. Conversion of ineffective podding period into effective podding period may increase podding duration and thus seed yield. This can be achieved by identifying genotypes which can continue to flower and set pods at low temperatures.

A beginning was made in 1982/83 with the breeders making six crosses which involved a cold tolerant genotype (from two different sources) as one of the parents. The F_3 material was supplied to us in 1984/85. From this we selected and advanced plants as bulks in groups different in respect of time to initiate flowering and also in cold tolerance (Chickpea Agronomy Report No.1, Section 4.6.). Single plant progenies thus selected were grown in this year.

Materials and Methods

This experiment was conducted at GLF, Hisar. Number of progenies planted varied from 15 to 21 in each flowering group and there were 12 such groups. These progenies were single plant selections, which were able to set pods at cool temperatures, selected last year. The source and the pedigree of these selections is described in Chickpea Agronomy Report No.1, 1985/86, Section 4.6. Each progeny was planted in 4 m long rows spaced at 60 x 20 cm on a flat seed bed prepared after a presowing irrigation.

A basal 20 kg P_2O_5 ha^{-1} as single superphosphate was applied before planting. The sowing was done on 2-11-1986 and a post-sowing irrigation was immediately given. Three weedings were done (November end, December end, mid-February) and the plants were also protected with insecticide sprays. Data on 50% flowering, podding initiation, maturity times were recorded. Shoot dry matter, seed yield, and 100 seed weight were recorded while harvesting at maturity (end of March to mid-April).

Results and Discussion

The ten top yielding selections in each flowering group are listed in Tables 4.2.1 to 4.2.6 with their phenology, yield and yield components. There was a wide range in mean flowering (91-98 days) and podding times (52-107 days) amongst the flowering groups whereas the maturity range was narrowed down (146-167 days), indicating the early podding entries to have a longer period of reproductive growth. The shoot dry matter and seed yield of entries of the first flowering group were considerably lower than

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that of the others, probably due to a limited growing period. Flowering groups II to V recorded higher production of shoot dry matter and seed yield, inspite of being early in maturity, and the mean harvest indices also showed some improvement. The 100 seed weight varied to a large extent among entries within a flowering group which would permit selection of lines with desirable combinations of growth duration and seed size. Definite conclusions can be drawn only when these lines are tested in adequately replicated large plots.

Table 4.2.1. Phenology, seed yield and yield components of 10 top ranking (on the basis of seed yield) cold tolerant selections of flowering groups I and II selected at Hisar, 1986/87.

Cold tolerant selection number	Days taken to 50% flow-ering	Podd-ing	Matu-rity	Shoot dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	100 seed weight (g)
Group I							
CTS 10580	40	52	143	8089	2600	35.3	20.7
CTS 10986	42	52	147	8132	2311	28.4	15.6
CTS 50770	40	53	146	4170	2309	55.4	13.6
CTS 10578	42	53	154	7089	2291	32.3	20.3
CTS 20650	42	53	143	3711	2057	55.4	15.6
CTS 10991	42	53	148	5650	2053	36.3	15.5
CTS 50605	40	53	144	4962	2047	41.3	10.9
CTS 10824	42	53	138	5463	2033	37.2	16.3
CTS 20600	41	50	152	5025	1977	39.3	12.9
CTS 50467	42	53	144	3336	1570	47.1	12.9
Mean	41	52	146	5463	2115	40.8	15.5
S.Em (±)	0.3	0.3	1.5	496.1	80.9	2.9	1.0
CV (%)	2.3	1.8	3.2	28.7	12.1	22.5	20.3
Group II							
CTS 50720	51	59	159	12260	4655	38.0	14.1
CTS 40324	44	58	138	9383	4527	48.3	17.4
CTS 10700	47	59	156	13136	4502	34.3	15.1
CTS 50793	46	59	162	9174	4435	48.3	11.1
CTS 50722	48	57	157	8757	4434	50.6	12.4
CTS 50683	52	59	159	10217	3997	39.1	11.3
CTS 50797	48	57	162	10008	3908	39.0	13.1
CTS 10571	51	59	154	13553	3789	28.0	16.2
CTS 10754	50	59	157	7339	3731	50.8	13.0
CTS 50537	45	56	159	7923	3685	46.5	11.7
Mean	48	58	156	10175	4166	42.3	13.5
S.Em (±)	0.9	0.4	2.2	677.1	119.5	2.45	0.67
CV (%)	5.7	1.9	4.4	21.0	9.1	18.3	15.7

Table 4.2.2. Phenology, seed yield and yield components of 10 top ranking (on the basis of seed yield) cold tolerant selections of flowering groups III and IV selected at Hisar, 1986/87.

Cold tolerant selection number	Days taken to 50% flow-ering	Podd-ing	Matu-rity	Shoot dry matter ($kg\ ha^{-1}$)	Seed yield ($kg\ ha^{-1}$)	Harvest index (%)	100 seed weight (g)
Group III							
CTS 50576	55	63	157	10425	4973	47.7	12.2
CTS 10962	56	64	155	16138	4767	29.7	18.0
CTS 60543	53	64	157	11676	4673	40.0	21.2
CTS 10702	53	63	156	10425	4391	42.1	17.7
CTS 50450	52	64	155	-	4306	-	-
CTS 10961	59	63	155	7131	4299	60.3	18.8
CTS 50562	52	63	155	9174	4296	46.8	10.9
CTS 50714	53	64	155	13219	4276	32.4	12.8
CTS 50556	55	61	157	-	4236	-	-
CTS 50718	54	64	157	11968	4199	35.1	-
Mean	54	63	156	9015	4444	41.8	15.9
S.Em (±)	0.7	0.3	0.3	1680.9	84.7	3.50	1.48
CV (%)	4.0	1.5	0.6	59.0	6.0	23.7	24.6
Group IV							
CTS 50860	51	67	167	8757	5488	62.7	11.5
CTS 50718	56	67	164	16430	5432	33.1	12.2
CTS 50888	57	65	155	10884	5197	47.7	11.2
CTS 60539	58	67	159	14428	5194	36.0	15.7
CTS 60486	58	67	157	11176	4894	43.8	16.8
CTS 60528	54	67	159	9674	4522	46.7	17.3
CTS 50664	56	66	157	9257	4508	48.7	12.5
CTS 50662	55	65	155	8966	4390	49.0	12.3
CTS 60488	58	67	159	9925	4372	44.1	17.3
CTS 60460	52	66	159	6505	4351	66.9	16.2
Mean	55	66	159	10600	4835	47.9	14.3
S.Em (+)	0.8	0.3	1.2	912.9	145.2	3.29	0.81
CV (%)	4.5	1.3	2.4	27.2	9.5	21.7	17.9

Table 4.2.3. Phenology, seed yield and yield components of 10 top ranking (on the basis of seed yield) cold tolerant selections of flowering groups V and VI selected at Hisar, 1986/87.

Cold tolerant selection number	Days taken to 50% flowering	Days taken to Podding	Days taken to Maturity	Shoot dry matter ($kg\ ha^{-1}$)	Seed yield ($kg\ ha^{-1}$)	Harvest index (%)	100 seed weight (g)
Group V							
CTS 30521	58	73	155	8715	4532	52.0	16.8
CTS 30518	58	73	155	8674	4425	51.0	17.1
CTS 10966	56	70	164	9341	4365	46.7	20.0
CTS 60532	58	73	155	9591	4220	44.0	18.0
CTS 11146	57	72	157	7047	3999	56.7	15.5
CTS 60478	56	71	155	8340	3863	46.3	18.6
CTS 20745	56	73	163	7631	3861	50.6	17.1
CTS 50668	57	72	155	8132	3740	46.0	14.4
CTS 40405	53	73	155	7506	3633	48.4	14.3
CTS 50564	60	73	155	7298	3467	47.5	12.8
Mean	57	72	157	8227	4010	48.9	16.5
S.Em (±)	0.6	0.3	1.1	272.7	114.0	1.17	0.70
CV (%)	3.2	1.5	2.2	10.5	9.0	7.6	13.4
Group VI							
CTS 40404	69	79	162	9841	4712	47.9	17.6
CTS 60537	68	78	163	8757	4258	48.6	16.2
CTS 20891	60	75	160	9758	4096	42.0	15.6
CTS 30514	62	79	161	8799	4095	46.5	18.4
CTS 21002	62	77	157	7047	3683	52.3	15.1
CTS 50059	68	77	163	6839	3582	52.4	13.6
CTS 50283	68	77	163	6255	3024	48.3	12.8
CTS 21247	68	79	161	5106	2708	53.0	13.4
CTS 20987	64	79	157	6338	2703	42.6	14.0
CTS 10998	63	76	157	6464	2600	40.2	16.6
Mean	65	78	160	7521	3546	47.4	15.35
S.Em (+)	1.0	0.4	0.8	518.3	237.3	1.4	0.59
CV (%)	5.1	1.8	1.6	21.8	21.2	9.6	12.1

Table 4.2.4. Phenology, seed yield and yield components of 10 top ranking (on the basis of seed yield) cold tolerant selections of flowering groups VII and VIII selected at Hisar, 1986/87.

Cold tolerant selection number	Days taken to 50% flowering	Days taken to Podding	Days taken to Maturity	Shoot dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	100 seed weight (g)
Group VII							
CTS 60505	69	84	161	8757	3696	42.2	16.4
CTS 11134	72	84	159	8966	3404	38.0	16.0
CTS 11123	67	80	155	6755	3072	45.5	18.5
CTS 60463	71	84	162	6881	2944	42.8	16.8
CTS 20793	74	80	159	5213	2629	50.4	14.8
CTS 20827	74	80	159	4670	2507	53.7	15.2
CTS 20759	72	80	160	4837	2431	50.3	15.7
CTS 11145	72	80	157	5421	2127	39.2	14.5
CTS 11304	73	83	160	5504	2112	38.4	20.7
CTS 11308	73	84	160	5171	2101	40.6	16.9
Mean	72	82	159	6217	2702	44.1	16.5
S.Em (±)	0.7	0.6	0.6	497.5	177.4	1.77	0.59
CV (%)	3.1	2.5	1.2	25.3	20.8	12.7	11.3
Group VIII							
CTS 50785	71	85	155	8757	4002	45.7	13.2
CTS 60516	67	87	164	11676	3912	33.5	18.1
CTS 40416	74	88	161	7089	3637	51.3	13.1
CTS 50070	83	90	161	8340	3512	42.1	10.9
CTS 50428	79	88	155	6881	3127	45.4	11.6
CTS 60469	66	88	164	7798	3036	38.9	19.9
CTS 20822	70	87	166	6672	3029	45.4	13.1
CTS 60504	70	88	164	8549	2881	33.7	21.0
CTS 20892	72	85	160	6297	2788	44.3	13.0
CTS 20826	75	88	167	5171	2718	52.6	14.6
Mean	73	87	162	7723	3264	43.3	14.8
S.Em (±)	1.7	0.5	1.3	563.0	147.7	2.04	1.12
CV (%)	7.2	1.7	2.6	23.0	14.3	14.9	23.8

Table 4.2.5. Phenology, seed yield and yield components of 10 top ranking (on the basis of seed yield) cold tolerant selections of flowering groups IX and X selected at Hisar, 1986/87.

Cold tolerant selection number	Days taken to 50% flowering	Days taken to Podding	Days taken to Maturity	Shoot dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	100 seed weight (g)
Group IX							
CTS 60553	79	94	161	17306	5532	32.0	14.5
CTS 50779	84	93	160	8132	4029	49.5	11.5
CTS 60185	89	95	163	7798	3509	45.0	13.3
CTS 50735	87	94	158	5921	3174	53.6	13.5
CTS 21352	79	91	160	6255	3148	50.3	12.6
CTS 60187	83	92	161	6047	2935	48.5	12.6
CTS 10969	86	93	160	8632	2904	33.6	17.7
CTS 50129	83	92	162	7131	2843	39.9	12.7
CTS 50402	86	95	162	8340	2786	33.4	15.2
CTS 20899	83	94	142	7089	2742	38.7	18.2
Mean	84	93	159	8265	3360	42.4	14.2
S.Em (±)	1.1	0.4	1.9	1050.0	271.4	2.51	0.71
CV (%)	4.1	1.4	3.8	40.2	25.5	18.7	15.8
Group X							
CTS 60119	88	96	173	8423	5261	62.5	13.1
CTS 40339	88	99	172	7548	4719	62.5	13.4
CTS 50425	88	96	169	10634	4349	40.9	12.4
CTS 60565	88	100	174	10217	4315	42.2	13.6
CTS 50404	90	97	173	9007	4256	47.3	10.2
CTS 50422	91	100	169	8799	4232	48.1	12.2
CTS 50783	88	100	169	8966	4184	46.7	11.5
CTS 10886	87	100	156	5338	3975	74.5	16.0
CTS 50379	90	96	173	9174	3972	43.3	11.4
CTS 50069	90	98	172	8340	3861	46.3	10.7
Mean	89	98	170	8644	4312	51.4	12.5
S.Em (±)	0.4	0.6	1.7	462.4	130.2	3.52	0.53
CV (%)	1.5	1.8	3.1	16.9	9.5	21.6	13.5

Table 4.2.6. Phenology, seed yield and yield components of 10 top ranking (on the basis of seed yield) cold tolerant selections of flowering groups XI and XII selected at Hisar, 1986/87.

Cold tolerant selection number	Days taken to 50% flowering	Podding	Maturity	Shoot dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	100 seed weight (g)
Group XI							
CTS 40259	92	102	169	7423	5366	72.3	11.7
CTS 50066	97	104	169	9174	4463	48.9	10.6
CTS 50361	96	102	169	8674	3525	40.6	12.9
CTS 50253	94	104	169	7589	3462	46.6	11.9
CTS 50093	97	104	169	7298	3294	45.1	11.6
CTS 50231	97	104	169	7214	3110	43.1	17.5
CTS 50243	95	105	169	7923	3065	38.7	12.1
CTS 50412	97	104	169	5921	3021	51.0	11.3
CTS 60373	94	102	169	6088	2976	48.9	23.0
CTS 50197	96	102	169	7715	2950	38.2	14.5
Mean	95	103	169	7502	3525	47.2	13.7
S.Em (±)	0.5	0.4	0.0	316.7	250.1	3.11	1.21
CV (%)	1.8	1.1	0.0	13.3	22.4	20.8	28.0
Group XII							
CTS 50388	98	106	164	9383	4417	47.1	11.9
CTS 50289	98	106	169	11092	4301	38.8	12.5
CTS 50195	98	107	165	7923	3415	43.1	11.3
CTS 60293	98	106	164	6755	3296	48.8	13.4
CTS 40249	100	108	167	7923	3206	40.5	11.3
CTS 50227	98	106	169	6714	3179	47.4	11.4
CTS 40241	98	106	167	7506	3173	42.3	11.6
CTS 50240	96	107	169	7923	3016	38.1	14.1
CTS 40247	100	108	167	7548	2971	39.4	12.6
CTS 50241	99	107	169	7131	2911	40.8	12.8
Mean	98	107	167	7990	3388	42.6	12.3
S.Em (±)	0.4	0.3	0.6	420.3	168.8	1.22	0.30
CV (%)	1.2	0.8	1.2	16.6	15.7	9.1	7.8

4.3 PA 86/39 Factors affecting yield of late planted chickpea at Gwalior (NPS)[1].

Introduction

Late planting of chickpeas in paddy fallows is an important cropping system in northern India. To study the factors affecting production in late planted chickpeas, an experiment was conducted at Gwalior in 1985-86 (Chickpea Agronomy Report No.1, Section 4.5). Factors studied were: two late dates of sowing, two levels of DAP application and two spacings. Yield was reduced by 10.6% due to irrigation (though not significant at P <0.005), by 24% in Dec 9 compared to Nov 29 planting and by 9.5% in 20 x 10 cm compared to 30 x 10 cm spacing, the latter two being significant at P <0.001. There was no significant effect of higher doses of DAP. The mean yield levels in different dates of planting were as follows:

Sowing date	Irrig.	Unirrig.
Oct 18 (Data from another trial)	2290	1878
Nov 29	1684	1877
Dec 9	1274	1433

A significant interaction between dates of planting and spacing was because the yields were not reduced due to closer spacing in Dec 9 plantings. We wished to repeat this experiment with ICCC 32, an ICRISAT entry, instead of K 850 and also include a normal date of planting for comparisons.

Materials and Methods

The experiment was laid out in a split-split plot design with four replications in field no.307. The main plots were two levels of irrigation: 1) nonirrigated, after a post-sowing irrigation and 2) irrigated twice or once in addition the post sowing irrigation. The subplots were sowing time and their irrigation schedule was as follows:

	Sowing 1	Sowing 2	Sowing 3
Sowing date	26-10-1986	26-11-1986	10-12-1986
Post-sowing irrigation given on	26-10-1986	28-11-1986	-
I treatment irrigation	28-11-86		
II treatment irrigation	2-2-1987	2-2-1987	2-2-1989

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The sub-sub plots were plant spacings at 1) 30 x 10 cm and 2) 20 x 10 cm. The sub-plots comprised basal fertilizer application levels of DAP and 200 kg DAP ha^{-1}. The sub-sub-plot size sown was 4.2 x 4 m on flat seed beds. The crop was weeded on 20-11-1986, 3-12-1986 and 31-1-1987. Plant samples were harvested at two stages of crop growth from an area of 0.6 m^2 in 30 x 10 cm spacing and 0.4 m^2 in 20 x 10 cm spacing treatments. These samples were harvested (during comparable phenological stages) on 24-1-1987 (90 DAS) and 23-2-1987 (120 DAS) from sowing I, 13-2-1987 (79 DAS) and 13-3-1987 (107 DAS) from sowing II and 24-2-87 (76 DAS) and 24-3-1987 (104 DAS) from the sowing III. The crop was harvested on 6-4-1987 and the plot sizes harvested at maturity were 3.0 x 3.0 m in the 30 x 10 cm spacing and 3.4 x 3.0 m in the 20 x 10 cm spacing.

Results and Discussion

The first growth analysis sample was harvested immediately after flowering, however the chronological age of the crop varied with sowing date. The total dry matter production at this crop growth stage was positively and significantly affected by irrigation, early planting, denser population and supplementary DAP application (Table 4.3.1). The plant components (root, stem, leaf, and reproductive parts) also showed a similar trend to that of total dry matter. (Tables 4.3.2. to 4.3.5.).

The second growth analysis sample was harvested at mid-pod filling stage. Total dry matter was significantly and considerably decreased with delayed sowing time. DAP application significantly increased the total dry matter production. Irrigation and higher plant density also increased dry matter production but these effects were nonsignificant (Table 4.3.6.). Dry weights of vegetative plant parts such as root and stem also showed responses similar to total dry matter (Tables 4.3.7 and 4.3.8). In addition, leaf dry weight was significantly increased by closer population under nonirrigated conditions (Table 4.3.9). The dry weight of reproductive parts was reduced by irrigation due to the delay caused by irrigation in flowering and pod set (Table 4.3.10). Delay in sowing time hastened the reproductive development. Irrigation failed to delay onset of podding in December sown crops. Reproductive growth was enhanced by 20 x 10 cm spacing only in the December sown crop.

Irrigation delayed 50% flowering by at least 3 days and delayed sowing time advanced this character (Table 4.3.11). Fertilizer addition delayed flowering under October sown conditions. Plant spacing did not influence the flowering time. Maturity of the crop was delayed considerably by irrigation and advanced when sown late (Table 4.3.12). Fertilizer application and dense population did not influence maturity.

Total dry matter production at maturity was increased by 66% with irrigation and by 15% with fertilizer. November sowing reduced dry matter by 19% and December sowing reduced it by 40% compared to October sowing (Table 4.3.13). Dense population increased dry matter production only in the nonirrigated treatment.

Seed yield response to irrigation was only 26% and this effect was nonsignificant. Response to fertilizer was 12% which was significant. The seed yield was significantly reduced with each level of delay in sowing (Table 4.3.14). There were 15% and 28% reductions in seed yield with November and December sowings, respectively.

There was a trend of harvest index to reduce with irrigation and to increase with late sowings (Table 4.3.15). Fertilizer and population did not affect this character. Surprisingly, the number of pods per plant was not affected by irrigation and sowing time (Table 4.3.16). The yield differences achieved by these inputs seems to be by altering the pod weight. Fertilizer treatment significantly increased the number of pods per plant. Seed number per pod increased with irrigation and dense spacing but the irrigation effect was nonsignificant (Table 4.3.17). None of the treatment factors influenced 100 seed weight significantly, whereas there was a decreasing trend with a delay in sowing time (Table 4.3.18).

December 10th planted chickpea seems to respond well to irrigation and fertilizer and was able to yield up to 1956 kg ha^{-1} under these conditions. Plant density played very little role in the yield increase.

Table 4.3.1. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer total dry matter g m^{-2} in chickpea at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	251.3	3.18***	2.9
Nonirrigated	187.3		
Sowing date			
Oct. 26	321.6	18.82***	24.3
Nov. 26	194.0		
Dec. 10	142.3		
Spacing (cm)			
30 x 10	177.3	10.10***	31.9
20 x 10	261.3		
Fertilizer (DAP)			
0 kg ha^{-1}	207.0	10.10	31.9
200 kg ha^{-1}	231.6		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV
Irrigated	351.0	215.5	187.4	1. 21.96	31.
Nonirrigated	292.2	172.8	97.1	2. 26.61	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	203.2	299.4	1. 10.59	31.
Nonirrigated	151.4	223.2	2. 14.29	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	280.4	362.8	1. 22.52	31.
Nov. 26	145.8	242.3	2. 17.50	
Dec. 10	105.8	178.8		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	232.9	269.7	1. 10.59	31.
Nonirrigated	181.2	193.4	2. 14.29	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	303.1	340.2	1. 22.52	31.
Nov. 26	188.8	199.3	2. 17.50	
Dec. 10	129.3	155.3		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	169.3	185.4	14.29	31.9
20 x 10 cm	244.8	277.8		

Table 4.3.2. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on root weight (g m^{-2}) of chickpea at flowering at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	21.1	2.00	21.3
Nonirrigated	16.4		
Sowing date			
Oct. 26	23.4	1.56**	23.5
Nov. 26	19.6		
Dec. 10	13.3		
Spacing (cm)			
30 x 10	15.4	0.92***	33.8
20 x 10	22.1		
Fertilizer (DAP)			
0 kg ha^{-1}	19.4	0.92	33.8
200 kg ha^{-1}	18.2		

Interactions (First order)

1. Sowing date x irrigation

	Oct.26	Nov. 26	Dec. 10	S.Em±	CV %
Irrigated	25.6	23.9	13.8	1. 2.69	33.8
Nonirrigated	21.2	15.2	12.9	2. 2.21	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	17.3	24.9	1. 2.20	33.8
Nonirrigated	13.5	19.4	2. 1.29	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	21.3	25.5	1. 1.92	33.8
Nov. 26	14.9	24.2	2. 1.59	
Dec. 10	10.0	16.7		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	21.5	20.7	1. 2.20	33.8
Nonirrigated	17.3	15.6	2. 1.29	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	23.7	23.2	1. 1.92	33.8
Nov. 26	20.0	19.1	2. 1.59	
Dec. 10	14.5	12.2		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	16.1	14.7	1.29	33.8
20 x 10 cm	22.7	21.6		

1. S.Em± for comparison of treatments in a cultivar.
2. S.Em± for comparison of cultivars in a treatment.
● Wherever there is only one S.Em, the same is to be used for making the above two comparisons.

Table 4.3.3. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on stem weight (g m^{-2}) of chickpea at flowering at Gwalior, 1986/87.

Main effects

Irrigation		S.Em±	CV %
Irrigated	113.7	3.30**	6.7
Nonirrigated	83.1		
Sowing date			
Oct. 26	153.1	10.22***	29.4
Nov. 26	82.5		
Dec. 10	59.6		
Spacing (cm)			
30 x 10	78.9	5.32***	37.5
20 x 10	117.9		
Fertilizer (DAP)			
0 kg ha^{-1}	88.5	5.32**	37.5
200 kg ha^{-1}	108.3		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 9	S.Em±	CV %
Irrigated	167.0	90.9	83.0	1. 12.25	37.5
Nonirrigated	139.2	74.0	36.2	2. 14.45	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	91.2	136.1	1. 6.26	37.5
Nonirrigated	66.6	99.7	2. 7.53	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	133.0	173.2	1. 12.12	37.5
Nov. 26	61.0	104.0	2. 9.22	
Dec. 10	42.6	76.6		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	100.3	127.0	1. 6.26	37.5
Nonirrigated	76.7	89.5	2. 7.53	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	135.3	170.9	1. 12.12	37.5
Nov. 26	78.9	86.1	2. 9.22	
Dec. 10	51.4	67.8		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10	73.5	84.2	7.53	37.5
20 x 10	103.5	132.3		

Table 4.3.4. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on leaf weight (g m^{-2}) of chickpea at flowering at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	114.2	1.37***	2.8
Nonirrigated	83.8		
Sowing date			
Oct. 26	145.4	7.36***	21.0
Nov. 26	87.4		
Dec. 10	64.2		
Spacing (cm)			
30 x 10	81.0	4.09***	28.6
20 x 10	117.0		
Fertilizer (DAP)			
0 kg ha^{-1}	96.0	4.09	28.6
200 kg ha^{-1}	102.0		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV %
Irrigated	159.4	97.1	86.0	1. 8.60	28.6
Nonirrigated	131.4	77.6	42.4	2. 10.40	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	93.4	135.0	1. 4.31	28.6
Nonirrigated	66.6	99.0	2. 5.78	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	126.8	164.0	1. 8.90	28.6
Nov. 26	66.8	107.9	2. 7.08	
Dec. 10	49.4	79.1		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	109.1	119.3	1. 4.31	28.6
Nonirrigated	83.0	84.6	2. 5.78	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	144.2	146.5	1. 8.90	28.6
Nov. 26	85.2	89.5	2. 7.08	
Dec. 10	58.7	69.8		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	77.5	84.5	5.78	28.6
20 x 10 cm	114.6	119.4		

Table 4.3.5. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on flower and pod weight (g m^{-2}) in chickpea at Gwalior, 1986/87.

<u>Main effects</u>

		S.Em±	CV %
Irrigation			
Irrigated	2.4	0.31*	19.8
Nonirrigated	3.9		
<u>Sowing date</u>			
Oct. 26	-0.3	0.60***	54.3
Nov. 26	4.6		
Dec. 10	5.1		
<u>Spacing (cm)</u>			
30 x 10	2.1	0.43***	94.4
20 x 10	4.2		
<u>Fertilizer (DAP)</u>			
0 kg ha^{-1}	3.1	0.43	94.4
200 kg ha^{-1}	3.2		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 29	Dec. 10	S.Em±	CV
Irrigated	-1.0	3.5	4.6	1. 0.76	94.
Nonirrigated	0.4	5.8	5.6	2. 0.85	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	1.3	3.4	1. 0.53	94.
Nonirrigated	2.8	5.1	2. 0.61	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	-0.6	0.0	1. 0.80	94.
Nov. 26	3.1	6.2	2. 0.74	
Dec. 10	3.8	6.5		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	2.0	2.7	1. 0.53	94.
Nonirrigated	4.1	3.7	2. 0.61	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	-0.1	-0.5	1. 0.80	94.
Nov. 26	4.7	4.6	2. 0.74	
Dec. 10	4.7	5.5		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	2.1	2.0	0.61	94.
20 x 10 cm	4.0	4.4		

Table 4.3.6. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on total drymatter (g m^{-2}) of chickpea at mid-podfilling at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	467	40.8	19.4
Nonirrigated	375		
Sowing date			
Oct. 26	513	28.7**	19.3
Nov. 26	406		
Dec. 10	344		
Spacing (cm)			
30 x 10	404	14.7	24.1
20 x 10	438		
Fertilizer (DAP)			
0 kg ha^{-1}	389	14.7**	24.1
200 kg ha^{-1}	453		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV %
Irrigated	543	421	437	1. 52.5	24.1
Nonirrigated	483	391	251	2. 40.6	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	465	469	1. 43.3	24.1
Nonirrigated	343	408	2. 20.7	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	504	522	1. 33.8	24.1
Nov. 26	411	402	2. 25.4	
Dec. 10	297	391		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	416	518	1. 43.3	24.1
Nonirrigated	361	389	2. 20.7	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	449	578	1. 33.8	24.1
Nov. 26	376	434	2. 25.4	
Dec. 10	340	348		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	358	460	20.7	24.1
20 x 10 cm	419	457		

Table 4.3.7. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on root weight (g m^{-2}) of chickpea at mid-podfilling at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	20.5	2.31	26.4
Nonirrigated	14.4		
Sowing date			
Oct. 28	26.4	1.83***	29.7
Nov. 26	20.1		
Dec. 10	6.0		
Spacing (cm)			
30 x 10	15.9	1.1*	42.0
20 x 10	19.1		
Fertilizer (DAP)			
0kg ha^{-1}	16.4	1.1	42.0
200 kg ha^{-1}	18.6		

Interactions (First order)

1. Sowing date x irrigation

	Oct.26	Nov. 26	Dec. 10	S.Em±	CV %
Irrigated	26.4	26.7	8.6	1. 3.13	42.0
Nonirrigated	26.3	13.5	3.4	2. 2.59	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm	S.Em±	CV %
Irrigated	19.0	22.1	1. 2.54	42.0
Nonirrigated	12.8	16.0	2. 1.50	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm	S.Em±	CV %
Oct. 26	25.1	27.6	1. 2.25	42.0
Nov. 26	17.5	22.7	2. 1.84	
Dec. 10	5.0	6.9		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}	S.Em±	CV %
Irrigated	19.6	21.5	1. 2.54	42.0
Nonirrigated	13.1	15.7	2. 1.50	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}	S.Em±	CV %
Oct. 26	25.6	27.1	1. 2.25	42.0
Nov. 26	17.9	22.3	2. 1.84	
Dec. 10	5.6	6.4		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}	S.Em±	CV %
30 x 10 cm	14.4	17.3	1.50	42.0
20 x 10 cm	18.3	19.9		

1. S.Em± for comparison of treatments in a cultivar.
2. S.Em± for comparison of cultivars in a treatment.

* Wherever there is only one S.Em, the same is to be used for making the above two comparisons.

Table 4.3.8. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on stem weight (g m^{-2}) of chickpea at mid-podfilling at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	222.1	24.25	26.2
Nonirrigated	148.0		
Sowing date			
Oct. 26	252.4	15.39***	23.5
Nov. 26	172.3		
Dec. 10	130.6		
Spacing (cm)			
30 x 10	172.7	9.84	36.8
20 x 10	197.4		
Fertilizer (DAP)			
0 kg ha^{-1}	161.9	9.84**	36.8
200 kg ha^{-1}	208.3		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 9	S.Em±	CV %
Irrigated	269.7	209.6	187.1	1. 30.07	36.8
Nonirrigated	236.1	134.9	74.0	2. 21.77	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	215.4	228.9	1. 26.17	36.8
Nonirrigated	130.0	166.0	2. 13.92	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	239.4	265.4	1. 19.55	36.8
Nov. 26	165.6	178.9	2. 17.04	
Dec. 10	113.0	148.1		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	183.1	261.2	1. 26.17*	36.8
Nonirrigated	140.7	155.3	2. 13.92	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	212.7	292.1	1. 19.55	36.8
Nov. 26	150.4	194.1	2. 17.04	
Dec. 10	122.6	138.6		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	145.5	199.8	13.92	36.8
20 x 10 cm	178.2	216.7		

Table 4.3.9. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on leaf weight (g m^{-2}) of chickpea at mid-podfilling at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	116.6	12.65	27.8
Nonirrigated	65.4		
Sowing date			
Oct. 26	126.2	6.88 ***	21.4
Nov. 29	83.5		
Dec. 10	63.3		
Spacing (cm)			
30 x 10	87.7	4.28	32.6
20 x 10	94.3		
Fertilizer (DAP)			
0 kg ha^{-1}	85.6	4.28	32.6
200 kg ha^{-1}	96.4		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV %
Irrigated	144.0	111.0	94.8	1. 14.94	32.6
Nonirrigated	108.4	56.0	31.8	2. 9.73	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	120.5	112.7	1. 13.36*	32.6
Nonirrigated	54.8	76.0	2. 6.06	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	117.6	134.7	1. 8.65	32.6
Nov. 26	85.3	81.7	2. 7.42	
Dec. 10	60.0	66.6		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	106.7	126.5	1. 13.36	32.6
Nonirrigated	64.5	66.3	2. 6.06	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	116.3	136.0	1. 8.65	32.6
Nov. 26	78.3	88.7	2. 7.42	
Dec. 10	62.0	64.6		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	76.3	99.0	6.06	32.6
20 x 10 cm	94.8	93.9		

Table 4.3.10. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on flower + pod weight (g m^{-2}) of chickpea at mid-podfilling at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	107.7	5.89*	9.2
Nonirrigated	149.1		
Sowing date			
Oct. 26	100.1	10.92*	24.0
Nov. 26	140.8		
Dec. 10	144.2		
Spacing (cm)			
30 x 10	122.7	6.14	33.1
20 x 10	134.1		
Fertilizer (DAP)			
0 kg ha^{-1}	127.6	6.14	33.1
200 kg ha^{-1}	129.2		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 29	Dec. 10	S.Em±	CV %
Irrigated	87.1	89.4	146.6	1. 13.91*	33.1
Nonirrigated	113.2	192.2	141.9	2. 15.44	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	100.0	115.3	1. 18.51	33.1
Nonirrigated	145.4	152.8	2. 18.68	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	106.6	93.6	1. 13.26**	33.1
Nov. 26	142.8	138.8	2. 10.64	
Dec. 10	118.7	169.7		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	108.4	107.0	1. 8.51	33.1
Nonirrigated	146.8	151.4	2. 8.68	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	97.2	103.1	1. 13.26	33.1
Nov. 26	135.8	145.8	2. 10.64	
Dec. 10	149.8	138.7		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	125.0	120.4	8.68	33.1
20 x 10 cm	130.1	138.0		

Table 4.3.11. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on days to 50% flowering in chickpea at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	74	0.7	1.9
Nonirrigated	71		
Sowing date			
Oct. 26	75	0.9**	3.7
Nov. 26	72		
Dec. 10	69		
Spacing (cm)			3.4
30 x 10	72	0.3	
20 x 10	72		
Fertilizer (DAP)			
0kg ha^{-1}	72	0.3	3.4
200 kg ha^{-1}	72		

Interactions (First order)

1. Sowing date x irrigation

	Oct.26	Nov. 26	Dec. 10	S.Em±		CV %
Irrigated	76	73	71	1.	1.3	3.4
Nonirrigated	74	71	67	2.	1.3	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm			
Irrigated	74	73	1.	0.8	3.4
Nonirrigated	71	71	2.	0.5	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm			
Oct. 26	75	75	1.	1.0	3.4
Nov. 26	72	72	2.	0.6	
Dec. 10	70	69			

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}			
Irrigated	73	74	1.	0.8	3.4
Nonirrigated	70	71	2.	0.5	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	74	76	1.0	3.4
Nov. 26	73	72	0.6	
Dec. 10	70	69		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	72	73	0.5	3.4
20 x 10 cm	72	72		

1. S.Em± for comparison of treatments in a cultivar.
2. S.Em± for comparison of cultivars in a treatment.
● Wherever there is only one SE m, the same is to be used for making the above two comparisons.

Table 4.3.12. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on days to maturity in chickpea at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	121	3.8	6.5
Nonirrigated	112		
Sowing date			
Oct. 26	128	2.6***	6.3
Nov. 26	116		
Dec. 10	106		
Spacing (cm)			
30 x 10	117	0.6	3.9
20 x 10	116		
Fertilizer (DAP)			
0 kg ha^{-1}	117	0.6	3.9
200 kg ha^{-1}	116		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 9	S.Em±	CV
Irrigated	134	121	109	1. 4.8	3.9
Nonirrigated	122	110	104	2. 3.7	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	122	121	1. 3.8	3.9
Nonirrigated	111	112	2. 0.9	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	128	128	1. 2.7	3.9
Nov. 26	116	116	2. 1.1	
Dec. 10	107	105		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	121	121	1. 3.8	3.9
Nonirrigated	113	111	2. 0.9	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	129	127	1. 2.7	3.9
Nov. 26	115	116	2. 1.1	
Dec. 10	107	106		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	117	117	0.9	3.9
20 x 10 cm	117	116		

Table 4.3.13. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on shoot weight (kg ha^{-1}) of chickpea at maturity at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	5667	435.2*	19.2
Nonirrigated	3406		
Sowing date			
Oct. 26	5665	334.3**	20.8
Nov. 29	4563		
Dec. 10	3381		
Spacing (cm)			
30 x 10	4671	184.4	28.2
20 x 10	4402		
Fertilizer (DAP)			
0 kg ha^{-1}	4216	184.4*	28.2
200 kg ha^{-1}	4857		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV
Irrigated	6621	6010	4370	1. 581.7	28.
Nonirrigated	4710	3116	2393	2. 472.8	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	6105	5229	1. 472.6*	28.
Nonirrigated	3238	3574	2. 260.8	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	5762	5568	1. 403.4	28.
Nov. 26	4766	4360	2. 319.4	
Dec. 10	3486	3277		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	5381	5953	1. 472.6	28.
Nonirrigated	3052	3761	2. 260.8	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	5414	5917	1. 403.4	28.2
Nov. 26	4243	4883	2. 319.4	
Dec. 10	2992	3771		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	4126	5217	260.8	28.2
20 x 10 cm	4306	4498		

Table 4.3.14. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on seed yield (kg ha^{-1}) of chickpea at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	1929	138.0	16.0
Nonirrigated	1533		
Sowing date			
Oct. 26	2019	118.5*	19.4
Nov. 26	1710		
Dec. 10	1462		
Spacing (cm)			
30 x 10	1757	65.5	26.2
20 x 10	1704		
Fertilizer (DAP)			
0 kg ha^{-1}	1634	65.5*	26.2
200 kg ha^{-1}	1827		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 28	Dec. 10	S.Em±	CV %
Irrigated	2191	1932	1664	1. 194.4	26.2
Nonirrigated	1848	1489	1261	2. 167.6	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	2025	1833	1. 152.8	26.2
Nonirrigated	1490	1575	2. 92.6	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	2008	2031	1. 143.1	26.2
Nov. 26	1821	1600	2. 113.4	
Dec. 10	1442	1482		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	1889	1969	1. 152.8	26.2
Nonirrigated	1379	1686	2. 92.6	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	1934	2105	1. 143.1	26.2
Nov. 26	1645	1775	2. 113.4	
Dec. 10	1323	1602		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	1604	1911	92.6	26.2
20 x 10 cm	1664	1744		

Table 4.3.15. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on harvest index (%) of chickpea at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	37.4	2.50	11.8
Nonirrigated	47.5		
Sowing date			
Oct. 26	37.9	1.76*	11.7
Nov. 26	42.7		
Dec. 10	46.7		
Spacing (cm)			
30 x 10	42.6	0.96	15.7
20 x 10	42.3		
Fertilizer (DAP)			
0 kg ha^{-1}	43.7	0.96	15.7
200 kg ha^{-1}	41.1		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV
Irrigated	34.9	36.8	40.4	1. 3.23	15..
Nonirrigated	40.9	48.5	53.1	2. 2.49	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	36.8	37.9	1. 2.68	15.7
Nonirrigated	48.4	46.6	2. 1.36	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	38.2	37.7	1. 2.12	15.7
Nov. 26	43.3	42.0	2. 1.66	
Dec. 10	46.4	47.0		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	39.0	35.7	1. 2.68	15.7
Nonirrigated	48.4	46.6	2. 1.36	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	38.6	37.2	1. 2.12	15.7
Nov. 26	44.3	41.0	2. 1.66	
Dec. 10	48.3	45.1		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	44.9	40.3	1.36	15.7
20 x 10 cm	42.6	41.9		

Table 4.3.16. Main effects and first order interactions of, sowing date, spacing and fertilizer on pod number per plant of chickpea at maturity at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	32.0	2.63	17.5
Nonirrigated	28.2		
Sowing date			
Oct. 26	28.2	2.42	22.7
Nov. 26	33.0		
Dec. 10	29.1		
Spacing (cm)			
30 x 10	34.5	1.40***	32.3
20 x 10	25.7		
Fertilizer (DAP)			
0 kg ha^{-1}	27.4	1.40**	32.3
200 kg ha^{-1}	32.8		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV %
Irrigated	30.8	36.1	29.0	1. 3.84	32.3
Nonirrigated	25.6	29.9	29.1	2. 3.42	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	37.7	26.2	1. 2.98	32.3
Nonirrigated	31.2	25.2	2. 1.98	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	32.6	23.8	1. 2.97	32.3
Nov. 26	37.0	28.9	2. 2.43	
Dec. 10	33.8	24.4		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	30.3	33.6	1. 2.98	32.3
Nonirrigated	24.5	32.0	2. 1.98	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	23.6	32.8	1. 2.97	32.3
Nov. 26	30.6	35.4	2. 2.43	
Dec. 10	27.9	30.2		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	29.6	39.4	1.98*	32. 3
20 x 10 cm	25.2	26.2		

Table 4.3.17. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on seed number per pod of chickpea at Gwalior, 1986/87.

Main effects

		S.Em±	CV %
Irrigation			
Irrigated	1.31	0.045	7.4
Nonirrigated	1.14		
Sowing date			
Oct. 26	1.23	0.060	13.8
Nov. 26	1.22		
Dec. 10	1.23		
Spacing (cm)			
30 x 10	1.16	0.045*	25.7
20 x 10	1.29		
Fertilizer (DAP)			
0 kg ha^{-1}	1.25	0.045	25.7
200 kg ha^{-1}	1.2		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV
Irrigated	1.32	1.29	1.33	1. 0.083	25.7
Nonirrigated	1.15	1.14	1.13	2. 0.085	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	1.20	1.43	1. 0.064	25.7
Nonirrigated	1.12	1.15	2. 0.064	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	1.17	1.29	1. 0.082	25.7
Nov. 26	1.13	1.30	2. 0.079	
Dec. 10	1.18	1.28		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	1.37	1.26	1. 0.064	25.7
Nonirrigated	1.12	1.15	2. 0.064	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	1.17	1.30	1. 0.082	25.7
Nov. 26	1.31	1.12	2. 0.079	
Dec. 10	1.26	1.19		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	1.16	1.17	0.064	25.7
20 x 10 cm	1.34	1.24		

Table 4.3.18. Main effects and first order interactions of irrigation, sowing date, spacing and fertilizer on hundred seed weight (g) of chickpea at Gwalior, 1986/87.

Main effects		S.Em±	CV %
Irrigation			
Irrigated	17.00	0.729	8.4
Nonirrigated	17.83		
Sowing date			
Oct. 26	17.96	0.875	14.2
Nov. 26	17.81		
Dec. 10	16.47		
Spacing (cm)			
30 x 10	18.15	0.717	28.5
20 x 10	16.69		
Fertilizer (DAP)			
0 kg ha^{-1}	17.48	0.717	28.5
200 kg ha^{-1}	17.36		

Interactions (First order)

1. Sowing date x irrigation

	Oct. 26	Nov. 26	Dec. 10	S.Em±	CV
Irrigated	16.93	17.47	16.60	1. 1.246	28.
Nonirrigated	19.00	18.16	16.35	2. 1.237	

2. Spacing x irrigation

	30 x 10 cm	20 x 10 cm		
Irrigated	17.55	16.45	1. 1.023	28.5
Nonirrigated	18.75	16.92	2. 1.014	

3. Spacing x sowing date

	30 x 10 cm	20 x 10 cm		
Oct. 26	19.34	16.59	1. 1.240	28.5
Nov. 26	18.30	17.33	2. 1.242	
Dec. 10	16.80	16.14		

4. Fertilizer x irrigation

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Irrigated	16.66	17.34	1. 1.023	28.5
Nonirrigated	18.29	17.38	2. 1.014	

5. Fertilizer x sowing date

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
Oct. 26	19.52	16.40	1. 1.240	28.5
Nov. 26	17.32	18.31	2. 1.242	
Dec. 10	15.59	17.35		

6. Fertilizer x spacing

	0 kg DAP ha^{-1}	200 kg DAP ha^{-1}		
30 x 10 cm	18.34	17.95	1.014	28.5
20 x 10 cm	16.61	16.76		

4.4 PA 86/40 Analysis of growth and yield of chickpea cultivars released for cultivation in India at different times (NPS, CJ)[1]

Introduction

We conducted a trial in 1985/86 (Chickpea Agronomy Report #1, Section 4.5) at Gwalior with eight cultivars of chickpea (recommended for cultivation in that region) at two levels of irrigation. The objective was to study genotypic differences in growth and yield of chickpea cultivars in the Gwalior environment. Cultivars that flower over a short duration of 60-75 days showed large differences in yield and ICCC 32, the top yielder, was a distinct outlier. Also, genotypes that differed widely in time to flowering (60--85 days), showed a narrow of variation in yield (2,000-2200 kg ha^{-1}). ICCC 40, was the earliest to flower (45 days) and appeared not suited to Gwalior and similar environments. We proposed to modify this trial and conduct it at Patancheru, Gwalior and Hisar during the 1986/87 season.

In the Indian Pulse Improvement Program a maximum of 38 chickpea cultivars have been released so far, as documented in a publication from Jabalpur. We wished to include the cultivars recommended for release in the three regions where the ICRISAT Center or Subcenters are located. The objective was to document "The changes in growth and other agro-physiological characteristics associated with the yielding ability of cultivars released over time". Such an analysis in soybean cultivars (John Boyer, 1982, Science 218: 443-447) released between 1935 and 1975 in USA showed that cultivars released in later decades were more tolerant of drought than those released in the early decades. This was not a character which was consciously bred for by including parents more tolerant to drought as selected for in droughty environments. Such an exercise in chickpea should permit us to determine the factors that have contributed to yield improvement in the three chickpea growing regions in India where the ICRISAT Breeding Program is carried out.

Materials and Methods

This trial was conducted at 3 locations - at ICRISAT Center and at ICRISAT subcenters, Gwalior and Hisar - and the cultural details adapted at these locations are listed in Table 4.4.1. Besides, the crops in all these places were kept weed free and the crop was regularly sprayed for insect pest control. The set of cultivars tested varied depending upon locations as per their adaptation and are listed in Table 4.4.2 together with their year of their release. At Gwalior, plants from an area of 0.6 m^2 were harvested at 32, 87 and 114 days after sowing in the nonirrigated treatment and 32 and 114 days after sowing in the irrigated treatment to estimate dry matter.

1. Compiled by L. Krishnamurthy

Results

ICRISAT Center

Plant stand and growth were affected in various degrees by early or late wilt depending upon the cultivar. Entries JG 62 and COG 1 were completely decimated by early wilt (data pertaining to these are hence not given) while Warangal, BEG 4882 and K 850 were affected by late wilt, more so under irrigated conditions, resulting in reduced growth and yield. Irrigation delayed 50% flowering and maturity of all the cultivars. The delay was more in early cultivars than in the medium ones (Table 4.4.3).

Dry matter production at maturity and seed yield in cultivars free from disease were approximately doubled, in general, with irrigation. These cultivars did not differ significantly in dry matter production and seed yield. Cultivar Chafa - an exception - being the earliest to flower and mature produced less dry matter and seed yield (Table 4.4.4). Irrigation reduced harvest index of the cultivars probably due to temperature and soil moisture stress during the extended reproductive growth phase. This reduction was considerable in cultivars Chafa, BEG 482, Warangal and K 850 because the late wilt incidence was severe with irrigation (Table 4.4.4).

Number of pods per plant was doubled with irrigation, except in the cultivars prone to disease, indicating this yield component to be the major yield determinant (Table 4.4.5). Irrigation tended to increase the number of seeds per pod. Number of seeds per pod significantly varied among cultivars with, cultivars BEG 482 and ICCC 37 having the highest number of seeds per pod. Irrigation did not affect the seed size significantly. The 100 seed weight of entries varied from 10 to 23 g.

ICRISAT Subcenter, Gwalior

Dry matter production at 32 days after sowing was not affected by irrigation and cultivars significantly differed in dry matter at this stage. Cultivars such as ICC 4958, ICC 10448 and Radhey produced a high amount of dry matter in all components (Table 4.4.6). However, at 87 and 114 days after sowing there were no significant difference between cultivars in dry matter production (Tables 4.4.7-9).

Irrigation effects on flowering time of cultivars was significant. In some cases flowering was advanced (i.e. C 235, H 208, ICC 32 and ICC 10985) while in other it was delayed (i.e. G2, L 550, ICCC 42, Radhey and T3). However, there was a significant wide range in flowering time of cultivars tested (Table 4.4.10). Irrigation delayed maturity of all cultivars and they matured almost at the same time, indicating a forced maturity (Table 4.4.10).

No significant differences due to irrigation, cultivar or irrigation x cultivar interaction were observed in shoot dry matter at maturity, inspite of a huge variation between irrigation means and among cultivaral means (Table 4.4.11). Seed yield responses were also similar to shoot dry matter. However, the mean cultivaral yields ranged from 1510 to 2317 kg ha^{-1} (Table 4.4.11). Irrigation reduced harvest indices significantly.

The means for cultivars ranged between 37.4 and 53.0% and even then these differences were nonsignificant. Such as variation in the yield and shoot dry matter was primarily due to lodging and diseases (Table 4.4.12).

Irrigation enabled the plants to produce significantly more pods while it did not affect the seeds per pod and 100 seed weight (Table 4.4.13). Cultivars differed significantly in number of pods per plant, seed number per pod and 100 seed weight. Cultivar T3 produced the highest number of pods per plant. Small seeded cultivars like C 235, H 208, G2, and T3 produced significantly higher number of pods per plant and seeds per pod as compensation.

ICRISAT Subcenter, Hisar

Irrigation, in general, did not cause any significant change in flowering and podding initiation time of various cultivars (Table 4.4.14). There were significant differences among cultivars in 50% flowering and maturity. Some cultivars such as K 968 and S 26 were distinctly early in flowering and podding initiation whereas some of them were early in flowering (i.e. C 214 and BG 209) which did not reflect in podding initiation. Irrigation significantly delayed maturity (Table 4.4.17). There were large differences in maturity time of the cultivars. Cultivars C 235 an K 468 matured approximately 28 days earlier than BG 209 or GL 769.

Irrigation significantly enhanced the dry matter production at maturity, which was almost double, whereas the yield increase was not to that magnitude due to poor harvest indices (Table 4.4.15). Dry matter production of the different cultivars did not vary much whereas the seed yield did. This was mainly due to the difference in yield potential and partitioning capability between Kabuli (L 144, C 104, etc.) and Desi (S26, K 850 etc.) chickpeas. Number of pods per plant and 100 seed weight did not improve with irrigation so as to explain the seed yield variation (Table 4.4.16). This could be attributed to the small sample size drawn for these yield component estimations (Table 4.4.16).

Discussion

In an effort to estimate the yield potential of various cultivars, an irrigation treatment was included in these trials. There were substantial yield and shoot dry matter increases with irrigation at ICRISAT Center and Hisar. Nevertheless, there were zero or negative responses in some cultivars which succumbed to disease. There was no such irrigation response in terms of either dry matter production or seed yield at Gwalior, which was most probably due to extensive lodging and disease incidence with irrigation.

No apparent yield improvements could be observed in the disease tolerant recent cultivars in comparison with the old ones. However, there seems to be considerable improvement made in incorporating disease tolerance in the recent cultivars.

Table 4.4.1. Cultural details for the trial analysis of growth and yield of chickpea cultivars released at different times in India, 1986/87.

Item	Location ICRISAT Center	ICRISAT Subcenter Gwalior	ICRISAT Subcenter Hisar
1. Field No.	BP 8C	Field No.307	Field No.1
2. Basal fertilizer	100 kg DAP ha^{-1}	100 kg DAP ha^{-1}	20 kg P_2O_5 ha^{-1} as SSP.
3. Seed bed	BBF	Flat	Flat
4. Design	Split plot	Split plot	Split plot
5. Main plot treatment			
Nonirrigated	One post-sowing irrigation (PSI) (on 31-10-86)	One PSI (on 26-10-86)	One PSI (on I week of Dec.)
Irrigated	One PSI + 4 more (on 28 Nov, 16 and 29 Dec 1986 and 13 Jan 1987)	One PSI + 2 more (on 27-11-86 and 2-2-87)	One PSI + one pre-sowing irrigation (on I week of Nov. 86)
6. Subplots (cultivars)	12	18	16
7. No. of replications	3	4	4
8. Spacing	30 x 10 cm	30 x 10 cm	30 x 10 cm
9. Fungicide (seed) treatment	0.5% Benlate T	-	-
10. Plot size sown	4 m x 4 rows	4.5 m x 4 m	4 m x 4 rows
11. Plot size harvested	3.6 m x 4 rows	3.3 m x 3 m	3.8 m x 4 rows
12. Date of sowing	28-10-86	26-10-86	11-11-1986
13. Date of sequential sampling	-	27-11-86, 2-1-87 17-2-87, and 2-4-1987	-
14. Date of harvest	17-2-87	2-4-1987	24/26-4-1987

Table 4.4.2. Varieties tested in the three locations and their year of release for cultivation in India.

ICRISAT Center		ICRISAT Sub Center Gwalior		ICRISAT Sub Center Hisar	
Variety	Year of release	Variety	Year of release	Variety	Year of release
Chafa	1940	G2	Before 1956	G 24	1958
COG 1	1953	T3	1959	S 26	1958
Annigeri	60's	C 235	1960	C 235	1960
JG 62	1972	Radhey	1968	C 104	1960
CPS 1	1976	L 550	1977	G 130	1971
BDN 9-3	1978	H 208	1977	C 214	1971
K 850	1978	K 850	1978	L 144	1976
Jyothi	1978	JG 315	1981	G 534	1977
Warangal	1979	ICCC 32	1984	H 208	1977
ICCC 37	1987	ICCC 42	90's	L 550	1977
ICCC 40	1989	ICC 4958	Germplasm	K 468	1978
ICCC 42	1989	ICC 10448	"	K 850	1978
		ICC 10985	"	BG 209	1980
		ICC 10991	"	Pant G 114	1981
				GL 769	1981
				Gaurav	1984

Table 4.4.3. Days taken to 50% flowering and maturity of some chickpea cultivars, released for cultivation in peninsular India at different times, grown at ICRISAT Center during 1986/87.

	50% Flowering (days)			Maturity (days)		
Cultivars	NI	I	Mean	NI	I	Mean
Annigeri	40	44	42	81	100	91
BDN 9-3	38	41	40	80	99	89
Chafa	38	41	39	79	88	83
BEG 482(Jyoti)	55	56	55	100	105	103
Warangal	40	43	42	81	87	84
K 850	48	50	49	89	104	97
CPS 1	43	46	44	84	103	93
ICCC 37	38	42	40	80	99	89
ICCC 40	40	42	41	82	100	91
ICCC 42	42	45	44	82	104	93
IMean	42	45		84	99	

	50% Flowering SE (+)		Maturity SE (+)	
Irrigation (I)	0.1	**	0.2	**
Cultivars (C)	0.2	***	0.3	***
I x C	0.3	**	0.5	**
I x C at the same level of I	0.3		0.5	
CV (%)	1.4		0.9	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.4. Shoot mass, seed yield and harvest indices of some chickpea cultivars, released for cultivation in peninsular India at different times, grown at ICRISAT Center during 1986/87.

	Shoot mass ($t\ ha^{-1}$)			Seed yield ($t\ ha^{-1}$)			Harvest index (%)		
Cultivars	NI	I	Mean	NI	I	Mean	NI	I	Mean
Annigeri	2844	6292	4568	1258	3156	2207	44.1	50.2	47.1
BDN 9-3	2774	5721	4247	1476	2535	2006	50.6	44.2	47.4
Chafa	2708	3154	2931	1125	927	1026	43.6	29.2	36.4
BEG 482(Jyoti)	2229	3961	3095	714	979	846	32.3	24.9	28.6
Warangal	1889	1588	1739	766	295	530	40.4	18.2	29.3
K 850	3115	4671	3893	1503	1517	1510	47.4	32.6	40.0
CPS 1	2536	6321	4428	1226	2927	2076	48.5	46.7	47.6
ICCC 37	2532	5931	4231	1467	3015	2241	57.7	50.8	54.3
ICCC 40	2551	5542	4047	1256	2718	1987	49.5	49.0	49.2
ICCC 42	2870	6066	4468	1635	3164	2399	57.0	52.2	54.6
Mean	2605	4925		1243	2123		47.1	39.8	

	SE (+)		SE (+)		SE (+)	
Irrigation (I)	168.9	**	141.4	*	1.41	NS
Cultivars (C)	148.7	***	92.0	***	2.29	***
I x C	261.4	***	187.7	***	3.38	**
I x C at the same level of I	210.3		130.1		3.24	
CV (%)	9.7		13.4		12.9	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.5. Yield components of some chickpea cultivars, released for cultivation in peninsular India at different times, grown at ICRISAT Center during 1986/87.

Cultivars	Filled pod number $plant^{-1}$			Seed number pod^{-1}			100 seed wt. (g)		
	NI	I	Mean	NI	I	Mean	NI	I	Mean
Annigeri	24	58	41	1.0	1.2	1.1	16.8	17.4	17.1
BDN 9-3	35	61	48	1.1	1.2	1.1	13.4	12.6	13.0
Chafa	28	27	28	1.1	1.3	1.2	13.9	9.4	11.7
BEG 482(Jyoti)	18	28	23	1.2	1.3	1.2	12.2	11.6	11.9
Warangal	20	13	17	1.0	1.1	1.1	12.4	8.8	10.6
K 850	19	26	23	1.0	1.1	1.1	24.5	21.5	23.0
CPS 1	22	54	38	1.1	1.3	1.2	16.3	15.3	15.8
ICCC 37	26	46	36	1.2	1.3	1.3	16.8	17.6	17.1
ICCC 40	27	52	40	1.1	1.2	1.1	17.0	16.2	16.6
ICCC 42	23	46	34	1.2	1.2	1.2	22.1	21.8	21.9
Mean	24	41		1.1	1.2		16.5	15.2	

	SE (+)		SE (+)		SE (+)	
Irrigation (I)	2.0	*	0.01	**	0.30	NS
Cultivars (C)	2.3	***	0.02	***	0.30	***
I x C	3.7	***	0.03	***	0.61	***
I x C at the same level of I	3.3		0.03		0.43	
CV (%)	17.3		3.9		4.7	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.6. Dry matter production at 32 days after sowing in some chickpea cultivars, released for cultivation in central India at different times, grown at ICRISAT subcenter, Gwalior during 1986/87.

	Root weight ($g\ m^{-2}$)			Stem weight ($g\ m^{-2}$)			Leaf weight ($g\ m^{-2}$)			Vegetative parts weight ($g\ m^{-2}$)		
Cultivars	NI	I	Mean	NI	I	Mean	NI	I	Mean	NI	I	Mean
ICC 10991	2.3	2.0	2.2	5.3	4.4	4.9	10.5	9.0	9.8	18.2	15.4	16.8
ICC 10448	2.5	2.1	2.3	7.0	6.3	6.7	14.3	13.1	13.7	23.9	21.6	22.7
ICC 10985	2.2	2.0	2.1	5.5	4.9	5.2	10.0	10.3	10.1	17.8	17.2	17.5
ICC 4958	3.9	3.3	3.6	9.4	8.0	8.7	18.3	14.9	16.6	31.6	26.3	29.0
Radhey	2.5	2.6	2.5	5.5	6.9	6.2	12.7	14.6	13.6	20.7	24.1	22.4
T 3	2.2	1.8	2.0	4.7	4.3	4.5	9.3	8.6	8.9	16.2	14.7	15.4
ICCC 32	2.4	3.0	2.7	5.6	7.5	6.5	11.0	14.1	12.6	19.0	24.5	21.8
ICCC 42	2.0	2.1	2.1	5.3	5.8	5.5	13.1	13.0	13.1	20.4	21.0	20.7
L 550	2.5	2.6	2.5	6.0	6.6	6.3	11.6	12.0	11.8	20.1	21.3	20.7
H 208	2.0	1.9	1.9	4.1	3.7	3.9	7.4	7.7	7.5	13.5	13.3	13.4
G 2	1.6	1.8	1.7	3.2	4.9	4.1	8.2	10.1	9.2	13.1	16.9	15.0
C 235	2.0	1.8	1.9	3.9	3.5	3.7	8.2	7.7	7.9	14.0	13.0	13.5
K 850	2.3	2.6	2.5	6.4	5.7	6.1	14.0	12.1	13.0	22.7	20.4	21.7
JG 315	2.4	2.0	2.2	5.8	5.0	5.4	12.3	10.7	11.5	20.6	17.6	19.1
Mean	2.3	2.3		5.6	5.5		11.5	11.3		19.4	19.1	

	SE (+)		SE (+)		SE (+)		SE (+)	
Irrigation (I)	0.04	NS	0.43	NS	0.75	NS	1.22	NS
Cultivars (C)	0.16	***	0.63	***	1.08	***	1.81	***
I x C	0.22	NS	0.96	NS	1.65	NS	2.75	NS
I x C at the same level of I	0.23		0.89		1.53		2.58	
CV (%)	19.9		32.0		26.9		26.6	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.7. Dry matter production at 87 days after sowing in some chickpea cultivars, released for cultivation in central India at different times, grown at ICRISAT subcenter, Gwalior during 1986/87.

Cultivars	Root weight (g m^{-2})	Stem weight (g m^{-2})	Leaf weight (g m^{-2})	Flower + pod weight (g m^{-2})	Vegetative parts weight (g m^{-2})
ICC 10991	21.8	78.0	108.3	1.61	208.1
ICC 10448	16.6	86.8	112.3	3.44	215.7
ICC 10985	18.5	82.7	117.6	4.04	218.8
ICC 4958	18.9	96.6	121.5	5.18	237.1
Radhey	19.8	100.3	109.3	0.07	229.3
T 3	16.0	80.0	99.9	0.00	195.9
ICCC 32	22.2	78.8	101.4	0.00	202.4
ICCC 42	17.4	76.6	114.9	3.01	209.0
L 550	22.2	89.7	116.2	0.00	228.1
H 208	17.7	75.4	97.8	0.00	190.9
G 2	18.1	77.5	113.4	0.17	209.0
C 235	22.5	83.0	109.6	0.00	215.1
K 850	20.3	87.8	113.8	0.60	221.9
JG 315	18.5	73.0	108.2	1.34	199.7
Mean	19.3	83.3	110.3	1.39	212.9
Siginificance	NS	NS	NS	NS	NS
SE (±)	2.65	14.10	10.26	1.49	24.42
CV %	27.4	33.9	18.6	213.9	22.9

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.8. Dry matter production at 114 days after sowing in some chickpea cultivars, released for cultivation in central India at different times, grown at ICRISAT subcenter, Gwalior during 1986/87.

	Root weight ($g\ m^{-2}$)			Stem weight ($g\ m^{-2}$)			Leaf weight ($g\ m^{-2}$)		
Cultivars	NI	I	Mean	NI	I	Mean	NI	I	Mean
ICC 10991	50.2	117.2	83.7	135.8	141.5	138.7	110.6	110.0	110.3
ICC 10448	38.9	71.9	55.4	159.4	165.7	162.6	173.2	145.6	159.4
ICC 10985	45.2	174.6	109.9	140.4	221.2	180.8	109.6	162.7	136.1
ICC 4958	36.2	97.8	67.0	138.3	214.2	176.3	60.5	153.9	107.2
Radhey	31.3	63.8	47.6	183.8	229.4	206.6	120.5	161.4	140.9
T 3	40.7	53.6	47.2	175.5	128.6	152.1	107.0	102.4	104.7
ICCC 32	52.8	108.6	80.7	182.9	268.6	225.7	100.3	147.9	124.1
ICCC 42	55.5	88.6	72.0	151.5	166.9	159.2	110.3	136.8	123.5
L 550	62.2	121.7	92.0	211.6	303.1	257.3	112.0	158.7	135.4
H 208	43.3	118.3	80.8	173.0	139.0	156.0	122.5	99.9	111.2
G 2	37.2	78.3	57.8	119.6	258.2	188.9	106.2	188.8	147.5
C 235	56.1	111.3	83.7	178.1	220.7	199.4	119.7	164.3	142.0
K 850	42.0	124.9	83.5	169.5	304.0	236.7	148.9	201.1	175.0
JG 315	42.0	56.9	49.4	203.5	164.3	183.9	145.7	136.9	141.3
Mean	45.3	99.1		165.9	209.0		117.6	147.9	

	Root weight SE (+)		Stem weight SE (+)		Leaf weight SE (+)	
Irrigation (I)	10.50	*	16.58	NS	8.43	NS
Cultivars (C)	14.35	NS	33.38	NS	17.51	NS
I x C	22.19	NS	48.41	NS	25.30	NS
I x C at the same level of I	20.29		47.20		24.76	
CV (%)	56.2		50.4		37.3	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.9. Dry matter production at 114 days after sowing in some chickpea cultivars, released for cultivation in central India at different times, grown at ICRISAT subcenter, Gwalior during 1986/87.

Cultivars	Flower+pod weight ($g\ m^{-2}$)			Vegetative parts weight ($g\ m^{-2}$)		
	NI	I	Mean	NI	I	Mean
ICC 10991	71.7	75.3	73.5	297	369	333
ICC 10448	56.4	41.3	48.8	333	383	358
ICC 10985	93.2	71.1	82.2	295	558	427
ICC 4958	30.3	19.4	24.9	235	466	350
Radhey	67.7	51.2	59.4	336	455	395
T 3	57.4	45.7	51.5	323	285	304
ICCC 32	56.4	52.9	54.7	336	525	431
ICCC 42	103.1	61.7	82.4	317	392	355
L 550	60.3	16.9	38.6	386	584	485
H 208	48.3	31.5	39.9	339	357	348
G 2	91.0	52.7	71.8	263	525	394
C 235	80.3	95.6	88.0	354	496	425
K 850	82.2	74.1	78.1	360	630	495
JG 315	59.8	88.9	74.3	391	358	375
Mean	68.4	55.6		326	456	

	SE (+)		SE (+)	
Irrigation (I)	3.88	NS	31.2	NS
Cultivars (C)	10.92	***	54.5	NS
I x C	15.39	NS	80.8	NS
I x C at the same level of I	15.45		77.1	
CV (%)	49.8		39.4	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.10. Days taken to 50% flowering and maturity of some chickpea cultivars, released for cultivation in central India at different times, grown at ICRISAT subcenter, Gwalior during 1986/87.

Cultivars	50% Flowering (days) NI	I	Mean	Maturity (days) NI	I	Mean*
JG 315	51	51	51	128	141	135
K 850	75	73	74	130	142	136
C 235	81	79	80	127	137	132
G 2	64	66	65	124	146	135
H 208	80	77	79	130	133	132
L 550	71	86	79	133	146	140
ICCC 32	75	68	72	130	138	134
ICCC 42	68	71	70	126	139	132
Radhey	70	77	74	126	141	133
T 3	67	77	72	129	142	136
ICC 4958	53	52	53	125	144	134
ICC 10448	60	59	59	130	144	137
ICC 10985	59	55	57	125	147	136
ICC 10991	58	58	58	126	139	132
Mean	67	68		128	141	

	SE (+)		SE (+)	
Irrigation (I)	0.9	NS	0.7	***
Cultivars (C)	2.4	***	2.3	NS
I x C	3.4	NS	3.2	NS
I x C at the same level of I	3.4		3.3	
CV (%)	10.1		4.9	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.11. Shoot mass, seed yield and harvest indices of some chickpea cultivars, released for cultivation in central India at different times, grown at ICRISAT subcenter, Gwalior during 1986/87.

	Shoot mass ($kg\ ha^{-1}$)			Seed yield ($kg\ ha^{-1}$)			Harvest index (%)		
Cultivars	NI	I	Mean	NI	I	Mean	NI	I	Mean
JG 315	5049	4681	4865	2358	2217	2370	56.0	49.9	53.0
K 850	3748	4888	4318	1905	1951	1928	51.5	40.9	46.2
C 235	4079	6593	5336	1539	2210	1875	39.7	35.0	37.4
G 2	2856	4639	3748	1340	1762	1551	43.6	41.2	42.4
H 208	4698	5324	5011	2024	1941	1982	48.6	41.8	45.2
L 550	3446	5101	4273	1544	2220	1882	43.7	46.3	45.0
ICCC 32	4175	3999	4087	1638	1980	1809	39.5	49.0	44.3
ICCC 42	3504	5450	4477	1667	2221	1944	47.4	44.0	45.7
Radhey	3236	4993	4115	1552	1985	1769	47.3	42.2	44.7
T 3	3994	4099	4047	1874	2006	1940	46.8	49.9	48.3
ICC 4958	2443	4181	3312	1297	1723	1510	57.6	46.9	52.2
ICC 10448	4910	5217	5064	2217	2369	2293	45.1	47.0	46.0
ICC 10985	2684	4728	3706	1499	2292	1895	55.7	49.2	52.5
ICC 10991	3686	2969	3327	1750	1578	1664	48.1	54.8	51.4
Mean	3751	4776		1729	2037		47.9	45.6	
		SE (+)			SE (+)			SE (+)	
Irrigation (I)		322.3	NS		171.4	NS		0.34	*
Cultivars (C)		575.8	NS		184.0	NS		4.11	NS
I x C		846.3	NS		303.8	NS		5.61	NS
I x C at the same level of I		814.3			260.2			5.81	
CV (%)		38.2			27.6			24.9	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.12. Visual scores in a 1-5 scale of lodging and disease in some chickpea cultivars, released for cultivation in central India at different times, grown at ICRISAT subcenter, Gwalior during 1986/87.

	Lodging score			Disease score		
Cultivars	NI	I	Mean	NI	I	Mean
JG 315	3.0	2.7	2.9	4.2	2.5	3.4
K 850	3.5	3.5	3.5	4.2	2.2	3.2
C 235	2.7	4.0	3.4	5.0	3.2	4.1
G 2	2.7	3.7	3.2	5.0	2.0	3.5
H 208	2.2	2.2	2.2	4.0	3.0	3.5
L 550	2.5	3.2	2.9	3.2	1.2	2.2
ICCC 32	2.7	3.7	3.2	3.2	1.5	2.4
ICCC 42	1.5	4.0	2.7	4.2	2.7	3.5
Radhey	2.7	3.5	3.1	4.7	2.2	3.5
T 3	1.7	2.5	2.1	4.7	1.7	3.2
ICC 4958	2.2	2.7	2.5	5.0	2.0	3.5
ICC 10448	3.5	3.5	3.5	4.5	2.7	3.6
ICC 10985	2.2	2.5	2.4	5.0	3.0	4.0
ICC 10991	1.5	2.0	1.7	5.0	3.7	4.4
Mean	2.5	3.1		4.4	2.4	

	SE (+)		SE (+)	
Irrigation (I)	0.07	**	0.16	**
Cultivars (C)	0.33	**	0.34	**
I x C	0.46	NS	0.49	NS
I x C at the same level of I	0.47		0.48	
CV (%)	33.6		28.0	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.13. Yield components of some chickpea cultivars, released for cultivation in central India at different times, grown at ICRISAT subcenter, Gwalior during 1986/87.

Cultivars	Pod number $plant^{-1}$ NI	Pod number $plant^{-1}$ I	Pod number $plant^{-1}$ Mean	Seed number pod^{-1} NI	Seed number pod^{-1} I	Seed number pod^{-1} Mean	100 seed wt. (g) NI	100 seed wt. (g) I	100 seed wt. (g) Mean
JG 315	37.0	49.9	43.4	1.22	1.32	1.27	15.8	13.1	14.5
K 850	28.3	53.5	40.9	1.17	1.08	1.12	25.1	20.6	22.9
C 235	37.9	48.4	43.1	1.39	1.41	1.40	11.6	12.2	11.9
G 2	32.1	76.0	54.0	1.21	1.21	1.21	12.4	13.4	12.9
H 208	51.1	49.2	50.1	1.37	1.33	1.35	10.3	11.5	10.9
L 550	43.9	41.4	42.7	1.00	1.16	1.08	18.6	20.4	19.5
ICCC 32	30.0	51.9	40.9	1.12	1.07	1.09	19.1	17.7	18.4
ICCC 42	32.4	42.1	37.3	1.06	1.13	1.09	19.9	20.6	20.2
Radhey	34.8	47.9	41.3	1.07	1.05	1.06	18.1	21.4	19.7
T 3	52.0	69.6	60.8	1.20	1.28	1.24	13.2	11.4	12.3
ICC 4958	22.6	30.4	26.5	1.05	1.02	1.04	27.1	27.9	27.5
ICC 10448	38.6	46.8	42.7	1.20	1.26	1.23	18.5	17.1	17.8
ICC 10965	37.3	45.9	41.6	1.25	1.36	1.31	13.0	13.0	13.0
ICC 10991	42.6	52.6	47.6	1.20	1.19	1.20	13.0	12.9	13.0
Mean	37.2	50.4		1.18	1.21		16.8	16.7	

	Pod number SE (+)		Seed number SE (+)		100 seed wt. SE (+)	
Irrigation (I)	2.59	*	0.016	NS	0.20	NS
Cultivars (C)	4.97	**	0.060	***	0.87	***
I x C	7.25	NS	0.083	NS	1.20	NS
I x C at the same level of I	7.03		0.085		1.23	
CV (%)	32.1		14.2		14.7	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.14. Days taken to 50% flowering, pod initiation, and maturity of some chickpea cultivars, released for cultivation in northern India at different times, grown at Hisar during 1986/87.

	50% Flowering (days)			Pod initiation (days)			Maturity (days)		
Cultivars	NI	I	Mean	NI	I	Mean	NI	I	Mean
C 214	78	75	77	107	106	107	152	158	155
G 24	80	76	78	95	98	97	134	136	135
G 543	86	84	85	102	99	101	153	155	154
C 235	91	93	92	93	91	92	130	132	131
G 130	98	99	99	104	105	105	150	156	153
Gaurav	74	68	71	100	109	104	146	150	148
K 468	81	77	79	90	92	91	126	137	132
H 208	92	93	93	113	115	114	149	151	150
L 144	99	100	100	109	105	107	131	135	133
C 104	80	77	79	104	103	103	139	143	141
Pant G 114	100	102	101	106	106	106	134	147	141
BG 209	75	76	75	118	113	116	158	161	160
S 26	67	72	70	90	99	95	130	133	132
GL 769	101	102	102	112	120	116	158	162	160
K 850	90	93	91	110	107	108	146	148	147
L 550	97	99	98	110	108	109	143	146	145
Mean	87	87		104	105		143	147	

	SE (±)		SE (±)		SE (±)	
Irrigation (I)	0.6	NS	0.5	NS	0.2	***
Cultivars	0.7	***	1.6	***	0.6	***
I x C	1.2	***	2.2	*	0.8	***
I x C at the same level of I	1.1		2.2		0.8	
CV (%)	2.5		4.3		1.1	

NI = Non irrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.001 level
* Significant at 0.05 level
NS Nonsignificant

Table 4.4.15. Shoot mass, seed yield and harvest index of some chickpea cultivars, released for cultivation in northern India at different times, grown at Hisar during 1986/87

	Shoot mass (days)			Seed yield (days)			Harvest (days)		
Cultivars	NI	I	Mean	NI	I	Mean	NI	I	Mean
C 214	4703	8802	6753	1728	2486	2107	37	30	33
G 24	3745	6568	5156	1667	1676	1672	45	26	36
G 543	4344	8677	6510	1866	2800	2333	45	32	38
C 235	4167	8323	6245	1635	2848	2242	43	36	39
G 130	5146	8724	6935	1962	2816	2389	41	33	37
Gaurav	4099	9104	6602	1814	2899	2357	48	33	40
K 468	4297	8307	6302	1523	2484	2003	38	29	34
H 208	3443	8396	5919	1665	2497	2081	48	31	39
L 144	3401	7016	5208	1004	1850	1427	31	29	30
C 104	3886	9910	6898	1218	3043	2131	29	28	28
Pant G 114	4711	8589	6650	2027	2959	2493	43	34	39
BG 209	4833	9505	7169	2071	2646	2359	49	29	39
S 26	4755	8099	6427	2251	3350	2800	47	42	44
GL 769	4214	8880	6547	1640	3072	2356	39	34	37
K 850	5927	7135	6531	2034	3366	2700	37	49	43
L 550	3667	6573	5120	1798	2118	1958	49	32	40
Mean	4334	8288		1744	2682		42	33	

	SE (±)		SE (±)		SE (±)	
Irrigation (I)	576.5	*	186.1	*	1.3	*
Cultivars (C)	563.6	NS	239.0	*	3.8	NS
I x C	963.3	NS	376.5	NS	5.4	NS
I x C at the same level of I	297.1		338.1		5.4	
CV (%)	25.3		30.6		28.9	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS

Table 4.4.16. Number of pods plant^{-1} and 100 seed weight some chickpea cultivars, released for cultivation in norther India at different times, grown at Hisar during 1986/87.

	Number of pods plant^{-1}			100 seed wt. (g)		
Cultivars	NI	I	Mean	NI	I	Mean
C 214	131	147	139	18.12	18.95	18.59
G 24	91	104	97	15.12	16.00	15.56
G 543	127	91	109	17.02	16.50	16.76
C 235	129	139	134	14.87	16.12	15.50
G 130	207	86	147	14.37	14.62	14.50
Gaurav	37	86	62	20.00	21.25	20.62
K 468	134	119	126	15.62	16.50	16.06
H 208	159	129	144	15.50	15.75	15.62
L 144	67	41	54	30.00	31.37	30.69
[illegible] 104	85	176	130	21.59	22.10	21.84
Pant G 114	121	104	112	15.50	16.25	15.87
[illegible]G 209	78	97	88	19.25	20.25	19.75
S 26	90	142	116	17.00	17.37	17.19
GL 769	76	131	103	15.12	16.50	15.81
K 850	53	79	66	29.00	29.75	29.37
[illegible] 550	86	103	94	22.47	22.75	22.61
Mean	104	111		18.79	19.50	

	SE (+)		SE (+)	
Irrigation (I)	2.5	NS	0.136	*
Cultivars (C)	17.3	***	0.268	***
I x C	23.88	*	0.392	NS
I x C at the same level of I	24.5		0.379	
CV (%)	45.4		4.0	

NI = Nonirrigated, and I = Irrigated

*** Significant at 0.001 level
** Significant at 0.01 level
* Significant at 0.05 level
NS Nonsignifant

4.5 PA 86/6 Multilocation testing of effects of solarization on pigeonpea and chickpea (YSC, CJ, YLN, NPH, Sardar Singh, KLS, JVDKKR, OPR, NPS).

Introduction

Large effects of solarization have been obtained on a wilt-sick Vertisol at ICRISAT Center (BIL72C) (Chickpea Agron. Rep.#1, Section 4.3). These have been obtained for both wilt resistant and susceptible genotypes of chickpea over a two year period. We thus wished to determine whether stimulatory effects of solarization on chickpea could be obtained on different soil types in different environments.

Materials and Methods

Experiments in 4 x 4 Latin Square design were done at ICRISAt Center, Gwalior and Hisar. Treatments were a factorial combination of with and without solarization and a wilt susceptible and resistant genotype. Plot size was 6 x 5 m with 2 m buffer between plots. Net plot area harvested was, however, 3.6 x 4 m. Other cultural details are given in Table 4.5.1. Solarization was done according to ICRISAT Research Bulletin No.11.

Results and Discussion

On BM 9A, which was essentially rainfed, there was no significant effect of solarization on weight of weeds harvested on 1 Dec. Solarization increased total dry matter (TDM) yield of ICCC 4 only, although it was only significant in the case of TDM (Table 4.5.2). Fusarium wilt reduced plant population in the unsolarized ICCC 4 plots.

At Gwalior, there were no clear effects of solarization on weed weight or composition. There were also no major effects on any other parameter measured (Table 4.5.3).

At Hisar, there was a suggestion that solarization increased plant height, but only significantly at 91 DAS (Table 4.5.4). Plant stand was reduced by salinity and solarization appeared to delay following and maturity (Table 4.5.5). Total dry matter, yield and yield components were not affected by solarization but yield of ICCV 17 significantly exceeded that of ICCC 41 (Table 4.5.6).

Table 4.5.1. Cultural details for the multilocation solarization trial for chickpea, 1986/87.

Item	Location		
	ICRISAT Center	Gwalior	Hisar
Field No.	BM9A	316	21
Pre-solarization irrigation	10/4/86		
Begin solarization	22/4/86	29/4/86	29/4/86
Complete solarization	4/6/86	16/6/86	Approx. after 6 weeks
Wilt susceptible cultivar	ICCC 4	ICCC 10466	ICCC 41
Wilt resistant cultivar	JG 74	GL 1002	ICCC 17
Date of sowing	15/10/86	17/10/86	11/11/86
Seed bed	BBF	Either side 60 cm ridges	Flat
Fertilizer	100 kg DAP ha^{-1}	100 kg DAP ha^{-1}	SSP at 20 kg P_2O_5 ha^{-1}
Spacing	30 x 10 cm	30 x 10 cm	37.5 x 10 cm
Pre-sowing irrigation	-	15/10/86	One
Post-sowing irrigation	16/10/86	18 and 49 DAS	-
Weeding	1/12/86	Presowing: 11/8, 19/9, 6/10/86 Postsowing: 17,37,69 DAS	10/12, 30/12
Sequential sampling		26/12, 17/1	PH at 15 day intervals from, 10/12. TDM at flowering
Date of h rvest	9-10/2/87	14/4/87	28/4/87

Table 4.5.2. Effect of solarization on phenology, growth, and yield parameters of wilt resistant (JG 74) and wilt susceptible (ICCC 4) chickpea cultivars on Vertisol (BM 9A) at ICRISAt Center, 1986/87.

Treatment	Days to 50% flowering	Days to maturity	Total dry matter (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)	Total pods m^{-2}	Filled pods m^{-2}	Total pods $plant^{-1}$	Filled pods $plant^{-1}$	Seed no pod^{-1}	100 seed mass(g)
JG 74, -Sol	47	100	1521	752	49.3	597	457	28	21	1.1	16.7
+Sol	47	98	1505	744	49.3	610	458	27	20	1.1	17.8
ICCC 4, -Sol	56	112	539	224	40.8	276	240	90	76	1.2	11.7
+Sol	56	110	1361	582	41.8	475	374	27	22	1.3	12.7
SEm[1]	±0.56	±0.276	±166.8*	±83.4	±1.47	±83.9	±74.0	±12.1*	±10.8*	±0.02**	±0.43

1. SEm for interaction term only as data were analyzed as RBD instead of Latin Square design.

Table 4.5.3. Effect of solarization on phenology, growth, nodulation, total dry matter (TDM) and yield of a wilt resistant (GL 1002, and wilt susceptible (ICC 10466) cultivar at Gwalior, 1986/87.

Treatment	At 70 DAS				At 91 DAS											
	Root dry mass (g plant^{-1})	Nodule dry mass (g plant^{-1})$^{-1}$)	Nodule no plant^{-1}	Stem + leaf dry mass (g plant^{-1})	Plant height (cm)	Root + nodule dry mass (g plant^{-1})	Nodulation rating	Stem leaf dry mass (g plant^{-1})	Days to 50% flowering	Days to maturity	TDM (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)	Pod no plant^{-1}	Seed no pod^{-1}	100 seed mass (g)
GL 1002, -Sol	0.26	0.072	3.3	1.37	26.4	0.40	2.27	2.63	86	134	4331	2133	49.2	30.2	1.50	11.6
, +Sol	0.29	0.055	3.3	1.42	25.1	0.37	1.40	3.77	85	133	3659	1811	49.7	35.0	1.39	11.2
ICC 10466,-Sol					20.1	0.39	2.50	2.47	87	141	3419	1664	48.5	31.9	1.31	9.9
+Sol					21.1	0.29	2.13	2.56	88	138	3279	1544	45.1	33.1	1.30	9.9
SEm	±0.163	±0.0162	±3.19	±0.163	±1.05*	±0.058	±0.305	±0.296	±1.9	±1.1*	±200.3	±109.3	±1.57	±7.96	±0.030*	0.34*

Table 4.5.4. Effect of solarization on plant height of wilt resistant (ICCV 17) and wilt susceptible (ICCC 41) chickpea cultivars at various growth stages at Hisar. 1986/87.

	Plant height (cm) at various days after sowing								
Treatments	29	44	60	75	91	106	121	136	152
ICCV 17									
Nonsolarized	13	18	23	29	37	48	50	52	52
Solarized	13	17	24	30	43	53	53	55	56
ICCC 41									
Nonsolarized	11	17	21	26	32	42	46	49	49
Solarized	10	16	20	27	38	49	49	54	55
SEm	±0.7	±0.3	±0.1**	±0.8	±0.8*	±1.7	±2.4	±3.6	±3.9

Table 4.5.5. Effect of solarization on plant stand, phenology and dry matter at flowering of chickpea cultivars at Hisar, 1986/87.

Treatments	Plant stand plot^{-1}		Days to 50% flower	Days to maturity	Dry matter at flowering (g)
	Initial	Final			
ICCV 17					
Nonsolarized	561	338	94	155	342
Solarized	509	275	96	157	368
ICCC 41					
Nonsolarized	599	375	89	151	221
Solarized	476	283	92	155	316
SEm	±65.4	±65.6	±0.4***	±0.7**	±33.3

Table 4.5.6. Effect of solarization on yield and yield components of chickpea cultivars at Hisar, 1986/87.

Teatments	Total dry matter (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	Pod no. m^{-2}	100 seed mass (g)
ICCV 17					
Nonsolarized	3192	534	17.5	1028	17.7
Solarized	5575	354	6.6	1105	19.3
ICCC 41					
Nonsolarized	2378	246	11.8	509	11.7
Solarized	4657	131	4.9	731	11.8
SEm	±686.5	±24.9	±2.14	±94.0	±0.50*

4.6 PA 86/8 Residual effects of solarization of chickpea and pigeonpea (YSC, CJ, YLN, MPH, NPS)

Introduction

The solarization experiments done during 1984 and 19885 indicated residual effects of solarization into the second year for both chickpea and pigeonpea. In order to determine the decay rate of the solarization effect we continued the experiments begun in 1984. We applied solarization only to those plots that had received solarization in both 1984 and 1985. We thus attempted to determined the rate at which a plot receiving solarization returns to the status of plots that have never been solarized.

Materials and Methods

The experiment was conducted on Vertisol field BIL 2C on the same plots as used in the 1984/85 and 1985/86 experiments (Chickpea Agronomy Prog. Rep. No.1 pp 28-41). Treatments were as follows:

Wilt reaction	Chickpea genotype	Solarization
1. Susceptible	ICCC 4	No sol. ever
2. Susceptible	ICCC 4	Sol. 84 only
3. Susceptible	ICCC 4	Sol. 85 only
4. Susceptible	ICCC 4	Sol. 84 + 85 + 86
5. Resistant	JG 74	No. sol. ever
6. Resistant	JG 74	Sol. 84 only
7. Resistant	JG 74	Sol. 85 only
8. Resistant	JG 74	Sol. 84 + 85 + 86

Plots were in randomized block design with 6 replications. The field was developed into BBF and plot size was 6 x 6 m. No basal nutrients or Rhizobium inoculum were added. Pre-solarization irrigation was given on 11 Apr 1986 and solarization began on 16/4 and terminated on 2/6, as described in ICRISAT Research Bulletin No.11.

A pre-sowing irrigation was given on 4 Oct. 1986. Sowing by vacuum planter was done on 14 Oct. and a post-sowing irrigation given the following day (effective date of sowing). One bed of some plots of ICCC 4 was used to impose fungal antagonist treatments, which have been reported by Dr M.P. Haware in Pulse Pathology Reports. Plant spacing was 30 x 10 cm.

The crop was harvested on 11 Feb. 1987.

Results and Discussion

Significance of main effects and interactions of treatment factors are given in Table 4.6.1. Genotypes differed significantly in all parameters asured and total dry matter (TDM) and grain yield were significantly affected by the solarization treatment and the interaction of genotype and solarization.

Fusarium wilt severely affected TDM and grain yield in nonsolarized plots of the wilt-susceptible cultivar ICCC 4 but there were substantial residual effects from solarization in previous years (Table 4.6.2). The yield components most affected by solarization treatment were pod number m^{-2} and pod number $plant^{-1}$ (Table 4.6.3).

The results of this study were combined with previous results from these plots and those of other trials to produce: Chauhan et al. 1988. Effects of Soil Solarization on Pigeonpea and Chickpea. ICRISAT Research Bulletin No.11.

Table 4.6.1. F ratios and significance for the residual solarization trial for chickpea in BIL 2C, 1986/87

	DF	Days to 50% flower-ing	Days to maturity	Total dry matter (kg ha^{-1})	Yield (kg ha^{-1})	Harvest index (%)	Pod no. m^{-2}	Pod no. $plant^{-1}$	Seed no. pod^{-1}	100 seed weight (g)
Genotype	1	788.0***	556.1***	78.1***	161.3***	185.5***	47.1***	19.3***	20.5***	111.9***
Solarization	3	2.9	0.9	17.2***	8.5***	2.6	3.7*	3.7*	0.2	0.4
Genotype x solarization	3	0.2	0.4	12.1***	4.0*	4.3*	0.6	4.7**	1.2	0.2

*Significant at 5% level
**Significant at 1% level
***Significant at 0.1% level

Table 4.6.2. Effect of solarization on phenology, aerial biomass, grain yield and harvest index of chickpea CVs JG 74 and ICCC 4, Field BIL 2C, 1986/87.

Cultivar	No solarization ever	Solarized 1984	Solarized 1985	Solarized 1984+85+86	SEm[1]
		Days to 50% flowering			
JG 74	43.8	43.3	43.2	44.7	±0.51
ICCC 4	54.0	53.3	53.7	54.7	
		Days to maturity			
JG 74	88.2	86.5	87.7	87.8	±0.76
ICCC 4	100.8	99.9	100.0	100.0	
		Total dry matter (kg ha^{-1})			
JG 74	1007	1055	1087	1084	±56.3
ICCC 4	337	608	810	1051	
		Grain yield (kg ha^{-1})			
JG 74	492	516	539	528	±27.95
ICCC 4	145	244	311	372	
		Harvest index (%)			
JG 74	48.9	48.8	49.6	49.6	±1.10
ICCC 4	42.2	39.2	37.8	35.4	

1 For interaction term

Table 4.6.3. Effect of solarization on yield components of chickpea CVs JG 74 and ICCC 4, Field BIL 2C, 1986/87

Cultivar	No solarization ever	Solarized 1984	Solarised 1985	Solarized 1984+85+86	SEm[1]
		Pod number m^{-1}			
JG 74	284	303	313	. 328	±22.61
ICCC 4	143	191	209	247	
		Pod number $plant^{-1}$			
JG 74	10	11	12	13	±6.0
ICCC 4	48	42	21	11	
		Seed number pod^{-1}			
JG 74	1.1	1.2	1.1	1.1	±0.033
ICCC 4	1.2	1.2	1.2	1.2	
		100 Seed wt. (g)			
JG 74	13.8	14.0	14.1	14.1	±0.33
ICCC 4	11.4	11.3	11.8	11.6	

1. For interaction term

4.7 **Visual scoring of GRU chickpea germplasm for early growth vigor, at ICRISAT Center and Gwalior**

Visual Scoring of GRU Chickpea Germplasm at ICRISAT Center on 8 December 1986

– C. Johansen

GRU and Pulse Agronomy had previously arranged to score seedling vigour and nodulation of chickpea germplasm. The main purpose of this was to identify genotypes that could form a closed canopy at the earliest and thus make maximum use of incident light. Of course, in the peninsular India environment due caution would have to be taken that such genotypes did not utilize all of the stored moisture before the pod-filling phase. For nodulation scoring, it was only intended to examine a few plants differing in their top growth to determine if there was any relation between nodulation and growth.

The plots consisted of 4 rows of 2 m length sown on 31 October 1986 on BBF in field BM 8C at ICRISAT Center. The number of germplasm accessions under test was 1320; all were short-duration genotypes. Checks such as Annigeri, L-550 and BDN-9-3 were placed at regular intervals. I understand that a post-sowing irrigation had been given. Visual scores of above-ground biomass were used to estimate seedling vigour. A scale of 1 to 5 was used, with 5 being maximum biomass. Firstly, standard plots were identified for constant reference throughout the scoring exercise. The best growing plot was designated 5 and the worst 1. Then an intermediate plot was identified and designated 3. The "2" standard was chosen as intermediate between 1 and 3 and "4" between 3 and 5. After the scoring exercise, 3 representative plants from each of these standard plots were harvested for dry matter determination of tops. Such samples were also taken from a further 12 plots which had scores over the range of the scale. By regressing dry weight against score, as done in Fig. 4.1, it is possible to calibrate visual score to dry matter values. It was noticed that the original 5 standards (Set A) provided a reasonably good relationship, even if slightly curvilinear ($y = -0.64 + 1.84x$, $r2 = 0.94$). However, the relationship was not so good when "scored standards" (Set B) were considered alone ($y = -2.46 + 2.96x$, $r2 = 0.67$) or together with the original standards ($y = -1.08 + 2.30x$, $r2 = 0.66$). These data indicate a tendency to give lower scores, in comparison to the original set of standards, for higher biomass plots.

At the time of scoring, many genotypes were beginning to flower. It was noticed that in most plots plants were suffering from water stress. The extent of this could be ascertained as there was leakage of irrigation water into some of the plots on the western side of the field. A plant sample taken from an Annigeri plot affected by irrigation (Plot No. 1840) had a dry weight 11.04 g/3 plants whereas an Annigeri plot nearby without irrigation (Plot No. 1873) had 4.28 g/3 plants; i.e. water stress in most of the plots was reducing growth to approximately 40% of well-watered plots. It should therefore be noted that the characterization given to this set of chickpea germplasm applies to water-stressed plants.

Accessions with the highest seedling vigour scores are shown in Table 1; however, the leakage of irrigation water would complicate interpretation of this. There were 51 accessions with a score of "4". The complete set of seedling vigour scores, together with other observations made (e.g. flowering, leaf type, plant habit, etc.) are with Pulse Agronomy. No obvious correlations between plant habit, leaf type, etc and seedling vigour score were noted, except perhaps an impression that K 850-type plants were relatively better.

For plants taken for dry weight determination, for standard calibration, the root systems were also dug up and visually scored for nodulation following Dr. O.P. Rupela's set of photographic standards. There was no relationship, visual or by regression analysis, between nodulation and shoot dry weight. All nodulation scores were between 3 and 4, indicating satisfactory nodulation in this field.

It may be concluded that this exercise could provide guidance in selecting genotypes that can optimize light use under the moisture stress conditions of rapidly receding soil moisture and high evaporative demand of the peninsular India environment. However, only early flowering and maturity types would be able to maximise pod set in such an environment if no further moisture became available.

Table 1. Chickpea plots scoring above 4 in a ranking of seedling vigour in GRU plots in field BM 8A at ICRISAT Center on 8 December 1986.

Plot No.	Accession No.	Score
848	6122	4.5*
880	5692	4.5*
882	12625	4.5*
1130	5697	5.0
1405	10957	4.5
1565	6126	4.5
1891	5685	4.5
2001	5804	5.0*

*Plot affected by leaking irrigation water.

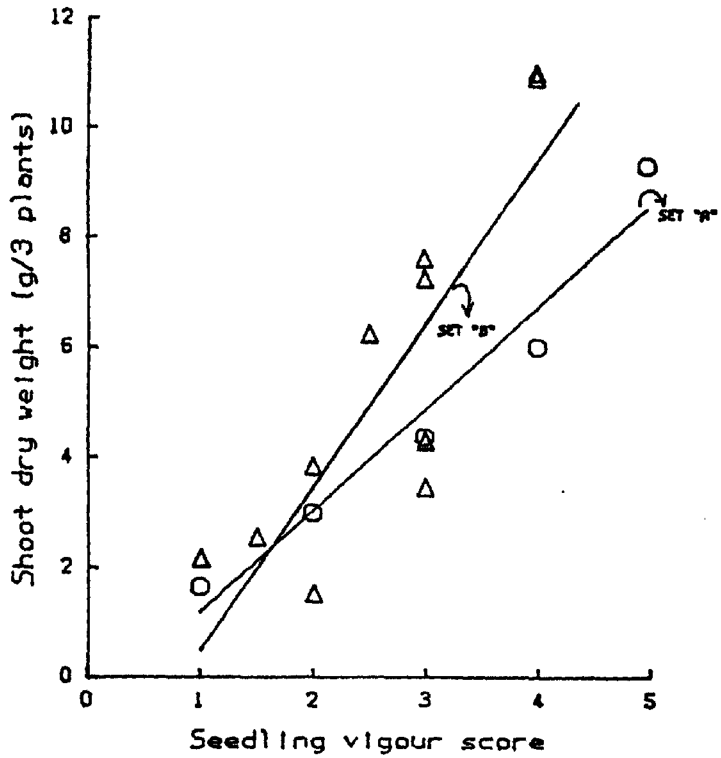

Figure 4.7.1. Relationship between shoot dry weights and seedling vigour scores given for GRU chickpea germplasm plots in field BM 8A at ICRISAT Center on 8 December 1986. O = original five standards chose (Set A); Δ = previously scored plots chosen for harvest (Set B).

Report on Visual Scoring of GRU Chickpea Germplasm at Gwalior on 13-14 Jan 1987

- O.P. Rupela

Plots were sown on 9 Nov 1986 on 60 cm ridges at 2 rows per ridge to give a spacing of 30 x 10 cm. Plot size was 4 rows of 2 m length. Irrigation had been given on 15 Dec and about 22 mm of rain was received in the second week of Jan.

Considerable time was spent in the selection of appropriate standards of plant biomass, as described in the ICRISAT Center report. Genotypes with different plant growth habits were also considered during this assessment. Uprooted plants were also scored for nodulation. There was no obvious correlation between growth score or shoot weight and nodulation score (Table 4.7.2).

Accessions scoring 5 are as follows: 567, 1255, 1191, 999, 1300, 525, 369, 1246, 611, 1231, 1177, L550, 11514, 1318, 1065, 365, 1472, 1093, 102, 590, 1227, 604, 144, 1327, 601, 1218, 1351, 1043, K850, 1002, 12487, 1266, 1017, 1088, 1365, 1042, 12469, 401, 1044, 1057, 1313, 1209, 1106, 452, 13819, 12254, 121, 1277, 4055, 1240, 1294, 1326, 1206, 1385, 69, 38, 209, 1000, 558, 359, 459, 384, 11088, 129, 244, 1348, 12489, 1270, 12237, 123, 10302, 1141, 1350, 162, 12433.

Table 4.7.2. **Shoot weight calibration and nodulation scores of chickpea in GRU plots at Gwalior, January 1987.**

Genotype	Score (Shoot growth)	Fresh weight of 4 shoots (g)	Dry weight of 4 shoots(g)	Mean nodulation score
<u>Initial standards</u>				
ICC 368 (Plot 760)	1	10.35	2.67	1.5
ICC 147 (Plot 328)	2	18.12	5.16	0.7
ICC 387 (Plot 822)	3	29.35	6.30	1.5
ICC 12481 (Plot 549)	4	49.44	11.33	2.5
ICC 79 (Plot 1165)	4	50.86	11.90	1.5
ICC 1294 (Plot 866)	5	78.38	15.80	1.3
ICC 1065 (Plot 110)	5	77.50	16.30	3.3
<u>Later standards</u>				
ICC 1292 (Plot 944)	4	33.72	8.00	3.0
K 850 (Plot 120)	5	81.04	18.32	4.7
K 850 (Plot 87)	4	50.56	10.40	5.0
ICC 420 (Plot 1158)	3	24.25	5.82	2.8
G 130 (Plot 778)	2	17.90	3.81	0.5

4.8. Demonstration block of ICCC 37

Chickpea Breeding and Pulse Agronomy decided to have a collaborative large-plot demonstration of a most promising chickpea cultivar with optimum input. ICCC 37 was chosen to be grown on a 49 x 48 m (2352 m^2) plot at the SE corner of BP 8C. The crop was dry sown by vacuum planter on 1.5 m BBF (32 beds) at 30 x 10 cm spacing on 28 Oct 1986. A post-sowing irrigation was given on 31 Oct, which was the effective date of sowing. Irrigations, by perfo, were subsequently applied on 27 Nov, 15 Dec, 24 Dec and 10 Jan. Weeding were done on 24 Nov and 9 Dec. Seed was treated with Benlate T and sprays of endosulphan (0.3% spray = 0.7 kg/ha) were given as required to protect against Helicoverpa (see FDO records for dates).

For comparison, some small plot (6 x 6 m = 4 beds of 6 m length) demonstrations were also grown just to the north of the large demonstration plot. Those were:

i. Annigeri, irrigated
ii. JG 62 (wilt susceptible), irrigated
iii. ICCC 37, Unirrigated
iv. ICCC 37, irrigated unsprayed.

Except where part of a particular treatment, they were grown under the same conditions as the large plot demonstration.

Date of 50% flowering in the large plot was 13 Dec. 1986 and date of maturity 4 Feb. 1987. By 39 DAS it was noticed that the demonstration plot was not covering well, due to both early stand loss by Sclerotium rolfsii and generally less than expected growth vigor. However, the canopy looked completely closed by 63 DAS.

A yield of almost 2 t/ha was finally realized from the large plot (Table 4.8.1); we were hoping for a yield of around 3 t/ha. The lower than expected yield could perhaps be attributed to sub-optimum plant stand and periods of drought stress at early growth stages (the soil seemed to dry very rapidly here); from initial signs of stress, the plants had to continue for several days under stress until irrigation could be arranged.

From the adjacent small demonstrate plots it could be seen that (Table 4.8.1):

a) Annigeri appeared to be matching ICCC 37 in yield

b) JG 62 readily succumbed to fusarium wilt, demonstrating the value of wilt-resistant cultivars.

c) Lack of irrigation halved yield of ICCC 37 and

d) Lack of insecticide protection also lowered yield.

Table 4.8.1. Data from demonstration plots in BP 8C, 1986/87.

Plot	Total dry matter (kg/ha)	Grain yield (kg/ha)	Harvest index (%)	Pod no. /m^2	Empty pod no./m^2	Seeds /pod	100 seed weight (g)
Large plot							
- ICCC 37	3671	1997	54	1255	361	1.4	15.4
Small plot							
- Annigeri	3962	2112	53	1220	253	1.3	16.0
- JG 62	820	128	16	153	167	1.0	9.2
- ICCC 37 unirrig.	1751	957	55	510	27	1.2	15.9
- ICCC 37 unsprayed	2956	1385	47	704	246	1.4	18.3

5. C-111(85)IC The alleviation of drought effects on growth, symbiotic nitrogen fixation capacity and yield of chickpea

5.1 Objectives

a. To quantify the response of growth, symbiotic nitrogen fixation and yield of chickpea to soil moisture deficit.

b. To identify genotypic variation in this response.

c. To understand specific mechanisms conferring resistance to drought stress in chickpea.

5.2 PA 86/34 Response of chickpea cultivar K 850 to soil moisture content of a Vertisol in a closed pot system (CJ, NPS)

Introduction

In the pot screening experiment for nutrient deficiencies of chickpea in Vertisol in 1985 (PA 85/23) plants grew poorly and appeared waterlogged (Chickpea Agron. Prog. Rep. No.1 PP. 160-167). Growth in a concurrent experiment in Alfisol appeared normal. The Vertisol soil was maintained at field capacity (33% moisture), according to the normal procedure for such trials. However, these results suggest that field capacity may not be the optimum moisture content for chickpea growing in a Vertisol.

In order to detect the potential for nutrient deficiencies in soils by the pot screening technique it is necessary to grow the plants with optimum soil moisture status, to allow maximum expression of any nutrient deficiencies. Thus it was considered necessary to determine the optimum soil moisture content for chickpea in Vertisol in the closed pot system used in nutrient screening studies. Plants were grown at moisture contents ranging from 15 to 40% and harvested at 20, 30, 40 and 50 days after sowing. The data generated also assists our understanding of the moisture requirements for early growth of chickpea in Vertisols.

Materials and Methods

Main plot treatments consisted of 15, 20, 25, 30, 35 and 40% (w/w) moisture in Vertisol from BR 4 (P. Agron. Soil Pit). However, the two lowest moisture treatments were initially maintained at 25% to ensure even germination and establishment. Sub-plot treatments were harvest dates: 28, 37, 45 and 57 DAS, following sowing on 7 Oct 1986. Pots were arranged in G/house 3, Bay 1 in split plot design with 3 replications (72 pots). Rerandomization was done at 13, 30 and 40 DAS. 3.78 kg oven dried soil sieved to 5 mm was placed in 20 cm polythene-lined plastic pots. Field capacity of this soil was 34.3%. Single superphosphate (SSP) at a rate of 1.257 g/pot (400 kg/ha SSP) was mixed in the surface 5 cm. Ten seeds of K 850 were sown per pot at 2-3 cm depth and inoculated with 10 ml rhizobial suspension (IC 76) per seed. 800 ml deionized water was added to each pot, and another 200 ml each on 9 and 11 Oct. Treatment irrigations were imposed on 15 Oct (8 DAS), when 150 g polythene beads were also added to each pot as a mulch. Plants were thinned to 7/pot on 17 Oct and to a final 3/pot on 22 Oct. At each harvest, oven dry weights of shoots and roots (including nodules) were determined.

Temperatures in the glasshouse were recorded on a thermohygrograph. Mean max/min temperatures ($\pm$ SE) during the growth period were 25.84 $\pm$ 0.416/16.88 $\pm$ 0.335^{o}C.

Results and Discussion

Soon after imposition of moisture treatments, at 8 DAS, plants at high moisture levels remained healthy in appearance but by 13 DAS signs of drought stress (e.g. upturned pinnules) were apparent at 15 and 20% moisture. Pots set at 15% did not actually reach that level until 34 DAS.

At the first harvest, at 28 DAS, optimum nodulation was apparent at 30% moisture with an abundant nodule mass at 3-4 cm below the cotyledons (6-7 cm below the soil surface). At 15 and 20% moisture, nodulation was retarded with only small protuberances apparent on roots.

At the second harvest, at 37 DAS, lower leaves of plants at 15% moisture were withering and dropping, with only the top 2 leaves remaining green. On these plants there were no nodules and the roots were black. Normal nodulation was apparent at 25% moisture and above. A longer root system had developed at 40% moisture, compared with a more "bushy" system at 25-35% moisture. These observations were also apparent by the third harvest at 45 DAS.

Plants at 35 and 40% moisture flowered first, at 49 DAS. At the final harvest, nodules at 25-40% moisture were intact and appeared active.

Treatment effects on each dry weights of shoots and roots are given in Table 5.2.1. It can be seen that growth increased with soil moisture content up to 35% at all harvests, with no apparent growth depression at 40% moisture. Thus the previously observed poor growth on Vertisol cannot be attributed to waterlogging effects. It is noted that this experiment was done in the normal chickpea growing period and thus high temperatures, with consequent high evopotranspiration should not have alleviated waterlogging effects in this particular study.

Table 5.2.1. Effect of soil moisture on shoot and root dry weights (g/plant) of chickpea (cv. K 850) grown in Vertisol in pots, Oct-Dec 1986.

Soil moisture (%)	Shoot weight (g/plant)				Root weight (g/plant)			
	28 DAS	37 DAS	45 DAS	57 DAS	28 DAS	37 DAS	45 DAS	57 DAS
15	0.149	0.160	0.140	0.104	0.229	0.213	0.202	0.164
20	0.165	0.227	0.251	0.335	0.266	0.355	0.326	0.355
25	0.234	0.410	0.644	0.986	0.390	0.596	0.658	1.030
30	0.349	0.672	1.009	1.889	0.439	0.669	0.845	1.577
35	0.412	0.942	1.468	2.976	0.455	0.857	0.969	2.408
40	0.373	0.811	1.398	3.337	0.423	0.803	1.007	2.105
SE								
- Moisture (M) effect	± 0.0362				± 0.0292			
- Harvest (H) effect	± 0.0318				± 0.0224			
- H x M	± 0.0734				± 0.0579			
- H x M at same level H	± 0.0725				± 0.0585			

5.3 PA 86/36 Determining the response to soil moisture of a range of chickpea genotypes using a line source sprinkler technique (CJ, NPS, SCS)

Introduction

In the 1985/6 Rabi season, a set of 20 chickpea advanced lines with controls was screened under line source (Chickpea Agronomy Prog. Rep. No.1 pp.82-96). The purpose of this was to determine relative response to a moisture gradient created by the line source sprinklers. There were considerable genotypic differences in the yields of seed and dry matter at the lowest and highest moisture levels, and in the slopes of plots of seed yield or dry matter yield against water applied.

However, unusually heavy rainfall during January and February of 1986 may have complicated interpretation of these responses, and the relative differences in response need verification. The technique itself seemed suitable in creating a moisture gradient for genotypic comparison in chickpea and it became apparent that the procedure could be adapted for mechanized sowing of large number of genotypes. It was intended to follow this procedure in this season. From these studies we hope to be able to determine whether the ranking in performance of a range of chickpea genotypes grow in one particular soil moisture regime differs significantly at other soil moisture regimes. This information is necessary to help formulate appropriate breeding strategies for chickpea to be grown in environments where inadequate soil moisture commonly limits yield of chickpea.

Materials and Methods

The 46 genotypes tested are listed in Table 5.3.3. ICC 4958 and ICC 10448 were drought resistant controls and ICC 11051 and ICC 10985 drought susceptible controls. Annigeri was included as a local general control of short duration and K 850 as a local general control of short to medium duration.

The experiment was conducted on Vertisol field BP 8C. The field had been prepared into a flat bed but no fertilizer was added due to suspected adequate levels (see Table 3.4 and results of mini-NP trials in this field, in Section 9.3). Two sprinkler lines were laid with sprinkler heads 6 m apart and with two heads extending beyond each end of the experimental area. Chickpea genotypes were sown in plots randomized in four blocks, one on each side of the two sprinkler lines. Each main plot was 4 rows wide and 15 m long (perpendicular to the line source). Distance between rows was 30 cm and within rows 10 cm (although seeds were sown 5 cm apart and later thinned to a 10 cm spacing). There was a gap of 60 cm between main plots. One dummy plot in each replication was used for neutron moisture measurements (probes at 3 m intervals from the line source) and here Annigeri was sown. This genotype was also sown as buffer plots at either end of experimental plots in each block.

Plastic buckets, for collecting water from the sprinklers, were placed at 1.5 m intervals from the sprinkler line at four locations in each replication. Two lines of buckets per block were in line with sprinkler heads and two between.

Seeds were sown on 26 Oct. 1986 at 5 cm within-row spacing, and later thinned to 10 cm spacing. Seeds were treated with Benlate T at 0.5%. No *Rhizobium* was applied. A post-sowing perfo irrigation was given on 31 Oct. (effective date of sowing) and seedlings emerged a week later. The plots were regularly hand weeded and thinned during 14-20 DAS (from effective date of sowing).

Line-source sprinkler applications were made on 1 Dec (31 DAS, 2 1/2 hrs), 9 Dec (39 DAS, 2 hrs), 23 Dec (53 DAS, 2 hrs) and 8 Jan (69 DAS, 1 1/2 hrs). Sprinkling was done after sunset when windspeed was less than 3 km/hr vertical to the line source and 8 km/hr parallel to the line source. Gravimetric (0-15 and 15-30 cm) and neutron probe soil moisture measurements were made on 12 occasions (see Table 5.3.2).

Intensive protection against *Helicoverpa* was provided by spraying endosulphan at 0.7 kg/ha, according to FDO schedules (records with FDO).

At harvest, on 12 Feb. 1987, the four rows in each 1.5 m sector were harvested separately, and estimates of aerial biomass and grain yield obtained.

In assessing moisture response, grain yield or total dry matter (TDM) for each sector was regressed against total water applied sector-wise.

Results and Discussion

Amounts of water appplied by the sprinklers to each sector and given in Table 5.3.1. Only 6.3 mm rain was received during December and 4.4 mm in the second week of January. Water distribution in profile over time is given in Table 5.3.2. Line-source sprinkling appeared to only temporarily recharge the top 45 cm of soil. Depths below that were relatively unaffected by sprinkler application.

As previously observed (Section 5.3 of Chickpea Agronomy Prog. Rep. No.1, pp. 82-96), drought stress hastened flowering and maturity in most genotypes (Tables 5.3.3. and 5.3.4.).

When growth and yield components in each sector were plotted against moisture applied by sprinklers, it was observed that linear relationships adequately fitted all genotypes (Table 5.3.5). Therefore, we compared genotypes on the basis of intercepts and slopes (Table 5.3.6). It should be noted that ICCS 10985 and 11051, ICCC 34, and ICCLs 83224, 84219, 85210 and 85211 were severely affected by disease (fusarium wilt) and hence interpretation of their moisture responses is not meaningful. K 850 was partially disease-affected and hence the validity of its moisture response is suspect.

Genotypes able to yield well under both moisture stressed and well-watered conditions (high intercept, high slope) include Annigeri, ICCV 10, ICCV 17, ICCL 84223 and ICCL 85225. Drought tolerant genotypes unable to perform well under high moisture conditions (high intercept, low slope) included ICC 4958, ICC 10448, ICCV 8 and ICCL 84303. Drought susceptible genotypes with reasonable yield potential under well-watered conditions (low intercept, high slope) included ICCC 47, ICCV 4, ICCV 5, ICCV 9, ICCL 82104, ICCL 82230, ICCL 83149, ICCL 83228, ICCL 84204, ICCL 85310, ICCL 85311 and ICCL 85333.

The drought tolerant controls, ICC 4958 and ICC 10448, again displayed their tolerance characteristic. Annigeri again ranked well under the entire range of moisture situations. K 850 displayed drought tolerance (low slope) but the overall yield level was reduced by disease, and because the season was shorter for this medium-duration genotype than the previous one (where it ranked high under low moisture in the line-source experiment in 1985/86).

Table 5.3.1. Total water applied (cm) by line source sprinklers in the drought screening trial on Vertisol (BP 8C) in 1986/87. Values are totals of four applications and means of four replications.

Sector									
1	2	3	4	5	6	7	8	9	10
13.84	13.44	12.98	11.83	9.80	6.57	3.22	0.76	0.04	0.00

S.Em ± 0.158***
CV (%) 8.7

Table 5.3.2. Soil moisture contents (% oven dry weight) in the line-source sprinkler trial on Vertisol, 1986/87. Mean of 4 replications.

Days after sowing	Soil depth (cm)	Distance away from the line source (m)				
		2.25	5.25	8.25	11.25	14.25
27	0-15	17.84	19.09	18.62	18.55	17.38
	15-30	24.45	24.38	24.90	24.59	24.91
	30-45	31.80	32.22	31.66	31.98	31.85
	45-60	32.46	35.37	35.12	35.52	35.74
	60-75	31.88	33.90	34.66	34.49a	36.03a
	75-90	28.87a	33.97b	33.12a	32.94a	33.63b
	90-105	33.19b	29.90c	26.77b	-	-
33	0-15	28.73	27.43	24.20	17.78	16.39
	15-30	24.68	24.53	22.90	22.66	23.69
	30-45	30.81	29.56	30.23	29.38	32.28
	45-60	33.11	35.13	34.60	35.13	35.10
	60-75	32.00	35.13	35.87	35.79a	35.28a
	75-90	29.05a	35.57b	33.69a	33.52a	33.58b
	90-105	32.58b	30.76c	28.06b	-	-
38	0-15	20.25	19.60	18.09	18.34	13.66
	15-30	20.94	20.41	20.31	20.17	20.88
	30-45	27.58	26.12	26.06	25.64	27.22
	45-60	29.52	32.27	32.53	31.06	32.00
	60-75	30.87	33.67	32.89	33.69a	34.09a
	75-90	28.51a	34.02b	31.39a	32.60a	32.11b
	90-105	32.35b	29.39c	26.60b	-	-
41	0-15	27.64	26.89	25.11	17.13	15.50
	15-30	28.08	24.28	21.38	20.74	21.18
	30-45	27.36	26.30	25.60	24.25	25.97
	45-60	30.73	31.48	31.51	29.45	30.89
	60-75	31.12	31.84	33.64	33.77a	32.90a
	75-90	27.89a	33.21b	31.87a	33.05a	32.67b
	90-105	33.98b	29.57c	27.03b	-	-
52	0-15	19.03	20.43	17.58	15.88	14.58
	15-30	22.07	20.05	21.68	19.77	20.66
	30-45	23.80	23.47	22.36	22.35	22.82
	45-60	26.02	27.18	26.02	24.41	25.14
	60-75	29.93	29.42	30.24	29.71a	28.12a
	75-90	28.75a	32.60b	31.66a	31.20a	30.78b
	90-105	33.53b	29.90c	27.57b	-	-
55	0-15	27.20	27.92	22.53	15.35	14.26
	15-30	26.69	23.41	21.09	19.75	20.83
	30-45	24.99	23.40	21.86	21.28	21.97
	45-60	25.88	25.85	24.32	23.40	23.75
	60-75	28.32	27.78	27.25	27.15a	27.10a
	75-90	27.74a	31.58b	29.14a	29.01a	29.25b
	90-105	32.56b	29.48c	26.86b	-	-

Table 5.3.2. Cont.

Days after sowing	Soil depth (cm)	Distance away from the line source (m)				
		2.25	5.25	8.25	11.25	14.25
69	0-15	19.26	18.40	17.27	13.88	13.85
	15-30	21.73	21.83	18.91	18.54	19.24
	30-45	22.61	22.18	20.99	20.96	21.04
	45-60	23.87	24.40	23.13	22.06	22.16
	60-75	25.77	25.25	24.02	23.26a	23.87a
	75-90	26.60a	27.62b	23.98a	24.40a	26.44b
	90-105	30.97b	29.34c	23.72b	-	-
71	0-15	28.76	27.85	23.78	16.94	13.94
	15-30	23.31	22.19	22.83	18.51	19.17
	30-45	22.78	21.88	20.56	20.33	20.53
	45-60	22.96	23.61	22.30	21.55	21.62
	60-75	25.25	24.16	23.49	22.72a	23.01a
	75-90	25.38a	27.14b	23.52a	23.29a	25.57b
	90-105	29.58b	28.67c	23.03b	-	-
80	0-15	19.16	19.03	17.85	15.79	14.05
	15-30	20.98	20.20	19.57	18.45	18.76
	30-45	22.15	22.02	20.32	20.30	20.52
	45-60	22.73	23.64	21.69	21.65	21.86
	60-75	24.61	24.67	22.66	22.55a	23.14a
	75-90	24.57a	26.98b	22.62a	23.14a	24.55b
	90-105	28.16b	27.42c	25.07b	-	-
88	0-15	17.18	16.02	15.53	14.28	12.99
	15-30	20.17	19.97	19.61	19.46	19.52
	30-45	20.53	20.51	20.16	20.43	20.61
	45-60	21.10	22.32	21.33	21.86	21.82
	60-75	22.94	23.21	22.45	22.36a	22.69a
	75-90	23.16a	23.94b	21.65a	23.07a	23.46b
	90-105	26.04b	23.83c	23.99b	-	-
94	0-15	15.48	15.49	14.67	12.79	12.96
	15-30	19.89	19.55	19.75	19.50	19.82
	30-45	20.13	20.48	20.34	20.52	20.77
	45-60	20.85	22.67	21.59	21.99	22.02
	60-75	22.66	23.47	22.55	23.01a	23.07a
	75-90	22.88a	24.45b	22.18a	23.45a	24.15b
	90-105	24.93b	24.38c	23.93b	-	-
102	0-15	14.66	14.94	14.02	12.52	13.16
	15-30	18.23	19.24	19.09	18.45	20.16
	30-45	19.62	20.24	20.05	20.53	20.89
	45-60	20.62	22.08	21.66	22.01	22.14
	60-75	22.33	22.53	22.21	23.04a	22.65a
	75-90	22.51a	23.58b	22.13a	23.09a	23.69b
	90-105	24.89b	23.82c	24.19b	-	-

a= values means of 3 reps, b= values means of 2 reps, c= Replication 2 values only
In surface soil layers (0-15 and 15-30 cm) moisture was gravimetrically assessed.

Table 5.3.3. Time of 50% flowering (DAS) of chickpea genotypes as affected by water gradient in a Vertisol. 1986/87.

Genotype	Sector										
	1	2	3	4	5	6	7	8	9	10	Mean
Annigeri	47	45	44	43	42	41	41	40	40	40	42
K 850	52	52	51	50	50	49	48	48	47	47	49
ICC 4958	33	33	33	33	33	33	33	33	33	33	33
ICC 8346	52	52	51	50	49	49	48	48	46	46	49
ICC 10448	49	48	46	42	41	40	40	40	40	40	42
ICC 10985	39	39	39	39	39	38	38	38	38	38	38
ICC 11051	42	42	41	39	39	39	38	38	38	38	39
ICCC 32	52	51	51	50	50	49	49	49	47	47	49
ICCC 34	51	51	50	50	49	48	48	48	47	47	49
ICCC 36	45	44	42	41	40	39	39	38	38	38	40
ICCC 37	43	42	42	41	41	40	39	39	38	38	40
ICCC 38	47	47	45	44	43	42	42	41	41	41	43
ICCC 42	48	48	47	46	46	43	42	41	41	42	44
ICCC 43	49	49	47	46	46	43	42	42	42	42	45
ICCC 47	42	42	42	41	41	40	39	39	39	39	40
ICCV 2	29	29	29	29	29	29	29	29	29	29	29
ICCV 3	37	37	37	37	37	36	36	36	36	36	36
ICCV 4	50	49	48	47	46	44	44	43	43	43	45
ICCV 5	47	47	45	44	44	42	42	41	42	42	43
ICCV 8	43	43	42	40	40	39	39	39	39	39	40
ICCV 9	45	45	43	42	41	41	39	39	39	39	41
ICCV 10	51	50	49	49	48	46	45	45	45	45	47
ICCV 17	44	43	43	40	40	39	39	38	38	38	40
ICCL 82104	42	42	41	39	39	39	38	38	37	38	39
ICCL 82230	44	43	41	41	39	38	38	37	37	37	39
ICCL 83149	45	44	42	42	41	40	39	39	39	39	41
ICCL 83224	33	33	33	33	33	33	33	33	33	33	33
ICCL 83227	47	46	44	44	43	43	42	42	42	42	43
ICCL 83228	48	47	45	45	44	43	43	43	43	43	44
ICCL 84204	48	47	42	40	40	40	38	38	38	38	41
ICCL 84205	50	49	48	45	43	42	42	41	40	41	44
ICCL 84215	51	50	49	49	49	47	46	46	45	45	48
ICCL 84219	51	51	50	49	48	47	46	44	44	44	47
ICCL 84223	46	45	43	43	41	41	41	40	40	40	42
ICCL 84303	52	51	49	49	47	44	43	41	41	41	46
ICCL 84311	43	42	41	41	39	39	39	38	38	39	40
ICCL 84327	52	51	50	49	48	47	46	45	45	45	48
ICCL 85210	44	43	42	41	41	40	39	39	38	39	40
ICCL 85211	44	43	42	41	41	40	39	39	39	38	40
ICCL 85225	45	45	43	42	41	41	41	41	41	41	42
ICCL 85307	48	47	45	42	41	40	40	40	39	40	42
ICCL 85310	53	53	52	52	51	50	49	48	47	47	50
ICCL 85311	51	51	50	49	49	48	47	46	46	46	48
ICCL 85314	52	52	51	50	49	49	47	47	47	47	49
ICCL 85325	60	60	60	59	59	59	58	58	58	58	59
ICCL 85333	52	52	51	50	49	49	48	48	47	47	49
Mean	46	46	45	44	43	42	42	41	41	41	

	S.Em±	CV (%)
For comparisons of means of genotypes	0.37	
For comparisons of means of genotypes x sectors	0.46	2.1

Table 5.3.4. Time of maturity (DAS) of chickpea genotypes as affected by water gradient in a Vertisol. 1986/87.

	Sector										
Genotype	1	2	3	4	5	6	7	8	9	10	Mean
Annigeri	96	94	93	91	88	86	84	82	81	82	88
K 850	98	97	95	93	91	91	90	89	89	89	92
ICC 4958	97	94	93	90	89	87	83	80	79	80	87
ICC 8346	102	99	97	94	93	91	90	89	88	88	93
ICC 10448	96	93	92	91	90	87	82	81	80	81	87
ICC 10985	94	93	92	90	89	88	86	82	82	82	88
ICC 11051	94	93	91	90	88	86	80	78	77	78	85
ICCC 32	98	97	96	93	93	92	91	90	90	90	93
ICCC 34	96	95	94	92	92	91	91	90	90	90	92
ICCC 36	96	93	91	90	89	86	82	80	80	80	87
ICCC 37	99	97	95	92	90	88	84	81	81	82	89
ICCC 38	97	94	93	92	91	88	85	82	81	82	88
ICCC 42	96	94	93	91	90	87	85	82	82	82	88
ICCC 43	95	93	92	91	89	87	84	83	81	82	88
ICCC 47	97	94	93	91	89	87	82	80	80	80	87
ICCV 2	87	86	83	81	80	79	77	74	72	71	79
ICCV 3	91	89	87	86	84	81	80	76	75	76	82
ICCV 4	97	95	94	92	90	89	87	84	84	84	89
ICCV 5	97	94	94	92	91	89	86	83	83	83	89
ICCV 8	98	96	94	92	89	88	86	82	80	81	89
ICCV 9	98	95	93	92	90	89	87	84	83	83	89
ICCV 10	100	97	95	93	91	90	88	87	86	86	91
ICCV 17	99	97	96	95	91	87	84	81	81	81	89
ICCL 82104	95	93	91	90	89	86	81	78	77	78	86
ICCL 82230	97	94	92	91	88	86	79	78	77	78	86
ICCL 83149	97	94	92	91	89	87	82	80	78	79	87
ICCL 83224	91	90	88	88	87	84	81	80	79	79	85
ICCL 83227	96	94	92	91	89	87	84	81	81	81	87
ICCL 83228	94	91	90	90	89	88	85	83	83	83	88
ICCL 84204	98	94	93	91	89	88	84	84	81	81	88
ICCL 84205	97	94	93	92	90	88	86	83	82	83	89
ICCL 84215	97	95	94	92	92	90	89	88	87	87	91
ICCL 84219	97	89	89	88	88	88	89	88	87	87	89
ICCL 84223	100	98	95	92	90	88	84	80	80	80	89
ICCL 84303	99	96	93	92	90	89	86	84	83	83	89
ICCL 84311	95	94	92	90	89	86	82	80	79	80	87
ICCL 84327	97	95	94	94	91	89	88	86	85	85	90
ICCL 85210	94	93	91	88	87	85	84	81	81	81	86
ICCL 85211	93	92	89	89	88	87	83	81	80	81	86
ICCL 85225	97	96	95	92	90	87	85	81	81	81	88
ICCL 85307	96	93	92	91	89	87	83	81	80	80	87
ICCL 85310	99	96	94	93	91	90	89	88	87	87	91
ICCL 85311	97	94	93	91	90	89	88	86	85	85	89
ICCL 85315	98	97	95	94	91	90	89	88	88	88	92
ICCL 85325	102	101	100	99	99	98	98	98	98	98	99
'CCL 85333	96	94	93	92	90	89	88	86	86	86	90
Mean	96	94	93	91	90	88	85	83	82	83	

	S.Em±	CV (%)
For comparisons of means of genotypes	0.75	
For cr[illegible]arisons of [illegible]ns of [illegible]notyp[illegible] [illegible]ctors	0.77	1.7

Table 5.3.5. Percentage variation accounted in a linear and quadtratic response of TDM and seed yield against moisture applied in a line source trial during 1986-87.

S.No.	Genotype	Percentage of variation accounted			
		TDM		Yield	
		Linear	Quadratic	Linear	Quadratic
1	ANNIGERI	94.2	95.3	91.9	91.6
**2	K-850	89.9	91.9	81.7	80.7
3	ICC-4958	96.8	98.0	96.3	96.9
4	ICC-8356	98.0	98.6	77.7	75.6
5	ICC-10448	98.2	98.5	91.6	92.5
*6	ICC-10985	92.2	92.4	83.2	80.8
*7	ICC-11051	93.2	94.8	91.4	92.1
8	ICCC-32	95.9	98.0	95.4	95.5
*9	ICCC-34	53.9	47.4	0.2	0
10	ICCC-36	96.6	98.7	96.1	95.8
11	ICCC-37	92.6	95.0	94.4	95.1
12	ICCC-38	98.7	98.8	98.5	98.5
13	ICCC-42	98.7	99.0	97.7	97.6
14	ICCC-43	94.4	97.0	80.5	87.1
15	ICCC-47	93.6	96.0	96.4	96.4
16	ICCV-2	95.2	97.5	94.5	98.7
17	ICCV-3	92.3	91.7	88.6	87.6
18	ICCCV-4	93.7	97.0	94.2	97.1
19	ICCV-5	94.5	96.6	97.2	97.6
20	ICCV-8	89.0	90.7	85.4	84.1
21	ICCV-9	96.0	97.0	98.3	98.1
22	ICCV-10	95.5	95.9	86.3	87.7
23	ICCV-17	96.6	98.6	96.4	96.3
24	ICCL-82104	98.9	99.2	71.6	67.7
25	ICCL-82230	91.3	96.1	95.7	97.6
26	ICCL-83149	88.7	89.7	91.1	91.2
*27	ICCL-83224	92.3	91.4	0	20.2
28	ICCL-83227	94.7	94.5	90.5	89.6
29	ICCL-83228	98.7	98.8	97.4	97.1
30	ICCL-84204	92.9	96.4	97.4	98.1
31	ICCL-84205	98.7	99.5	98.3	98.1
32	ICCL-84215	91.2	95.4	73.7	72.1
*33	ICCL-84219	12.8	1.7	79.6	79.8
34	ICCL-84223	99.3	98.9	97.2	97.4
35	ICCL-84303	97.1	97.2	96.0	96.7
36	ICCL-84311	95.3	96.3	94.7	94.8
37	ICCL-84327	99.6	99.6	97.6	99.2
*38	ICCL-85210	92.5	91.6	0	13.5
*39	ICCL-85211	89.3	88.5	37.1	44.7
40	ICCL-85225	96.6	97.5	98.1	98.0
41	ICCL-85307	97.1	97.8	94.6	96.0
42	ICCL-85310	88.8	88.7	92.2	91.5
43	ICCL-85311	96.0	96.3	97.2	97.0
44	ICCL-85314	96.7	97.9	97.9	97.9
45	ICCL-85325	95.3	96.6	95.8	95.4
46	ICCL-85333	89.4	93.6	87.7	91.0

* Affected by disease severely.
** Affected by disease in some replications.

Table 5.3.6. Genotypic comparison of moisture response under line-source sprinklers as measured by components of linear regressions of plant growth and yield on water applied.

S.No.	Genotype	Above-ground biomass (g/m2)				Seed yield (g/m2)			
		Intercept	Slope	r2	rse	Intercept	Slope	r2	rse
1	Annigeri	283.6	21.4	94.2	30.9	163.2	10.6	91.9	18.2
**2	K 850	247.4	18.6	89.9	36.1	127.3	6.6	83.2	17.1
3	ICC 4958	256.3	21.2	96.8	22.4	152.0	7.4	94.8	10.0
4	ICC 8346	270.5	21.2	98.0	17.4	123.0	8.0	96.3	9.1
5	ICC 10448	262.5	19.2	98.2	15.2	159.0	8.7	98.1	7.1
*6	ICC 10985	164.4	9.1	92.2	15.3	86.4	1.9	83.2	4.9
*7	ICC 11051	186.1	16.6	93.2	26.1	102.8	7.3	91.4	13.0
8	ICCC 32	254.5	22.8	95.9	27.4	110.4	9.2	97.8	8.1
*9	ICCC 34	222.2	10.9	83.8	27.7	93.3	2.7	59.1	12.5
10	ICCC 36	205.8	20.1	96.6	22.0	112.6	9.2	97.8	8.0
11	ICCC 37	256.4	23.8	94.0	35.0	146.5	10.9	96.1	12.8
12	ICCC 38	235.7	21.1	98.7	14.2	127.4	9.4	97.7	8.4
13	ICCC 42	247.7	19.9	98.7	13.3	136.8	9.3	98.6	6.5
14	ICCC 43	225.5	22.0	95.9	26.6	114.9	9.6	96.4	10.8
15	ICCC 47	205.5	22.9	95.4	29.2	114.0	10.1	96.4	11.4
16	ICCV 2	170.8	17.0	94.5	23.8	88.3	7.9	94.8	10.6
17	ICCV 3	176.9	16.6	92.7	27.1	107.2	8.8	92.0	15.0
18	ICCV 4	200.1	23.5	94.5	33.0	105.1	10.9	94.8	14.7
19	ICCV 5	203.9	24.1	94.9	32.4	104.3	10.9	97.9	9.3
20	ICCV 8	272.3	20.2	89.0	41.1	150.6	8.5	90.5	16.0
21	ICCV 9	221.9	23.0	96.0	27.4	115.2	11.2	98.9	6.9
22	ICCV 10	312.9	23.1	95.5	29.2	170.9	10.7	93.3	16.7
23	ICCV 17	263.7	29.0	97.3	28.1	151.8	10.0	97.8	8.7
24	ICCL 82104	234.4	22.2	98.9	13.8	129.8	10.2	97.4	9.6
25	ICCL 82230	194.5	24.8	91.3	44.4	115.5	10.1	95.7	12.5
26	ICCL 83149	200.1	25.1	88.7	51.9	113.3	12.8	91.1	23.3
*27	ICCL 83224	208.1	9.2	92.3	15.5	109.2	1.4	13.4	16.2
28	ICCL 83227	252.6	20.2	94.7	27.7	140.0	9.7	92.4	16.1
29	ICCL 83228	216.7	20.5	98.7	13.8	125.3	11.8	99.2	6.0
30	ICCL 84204	228.9	25.1	92.8	40.4	130.0	12.0	98.6	8.4
31	ICCL 84205	258.9	21.4	98.7	14.2	147.1	8.8	98.3	6.7
32	ICCL 84215	283.2	22.2	95.5	27.8	124.5	9.9	92.4	16.4
*33	ICCL 84219	155.1	-1.9	12.8	21.8	65.9	-3.4	79.7	9.9
34	ICCL 84223	265.8	25.4	98.3	19.6	151.6	11.3	97.2	11.1
35	ICCL 84303	273.7	20.5	97.1	20.5	157.3	8.2	96.0	9.7
36	ICCL 84311	234.9	18.1	95.2	23.6	141.4	9.4	98.1	7.7
37	ICCL 84327	240.5	21.4	99.6	8.2	122.5	9.6	98.4	7.0
*38	ICCL 85210	264.5	12.2	95.4	15.7	152.6	0.6	0.0	14.5
*39	ICCL 85211	267.9	12.3	89.3	24.7	150.7	2.0	37.1	14.3
40	ICCL 85225	272.0	24.0	96.5	26.4	152.5	10.2	98.1	8.2
41	ICCL 85307	241.0	18.2	96.9	18.9	143.6	8.8	94.6	12.2
42	ICCL 85310	244.3	21.2	90.3	40.4	118.0	10.6	93.5	16.2
43	ICCL 85311	205.0	20.0	96.5	22.2	108.5	10.6	97.2	10.4
44	ICCL 85314	214.1	20.3	96.5	22.5	101.3	9.2	98.3	7.1
45	ICCL 85325	232.2	17.4	96.8	18.4	87.6	6.9	97.4	6.6
46	ICCL 85333	226.6	23.1	89.3	46.2	117.4	10.8	87.7	23.3

* Affected by disease severely.
** Affected by disease in some replications.

5.4 Response of advanced chickpea genotypes to irrigation (CJ, HAvR, OS).

Chickpea Breeding and Pulse Agronomy decided to jointly test promising chickpea genotypes under both rainfed and optimally irrigated conditions. Chickpea Breeding were to provide the genotypes for testing and Pulse Agronomy to conduct the test with +/- irrigation in large plots.

Genotypes Annigeri (control), ICCV 1, ICCC 32, ICCC 37 and ICCC 42 where compared as subplots in main plot treatments of + and - irrigation in a split plot design in BP 8C. Subplot size was 6 x 10 m (4 BBF, 10 m long). Seeds were treated with benlate + thiram (5%). Dry sowing was done on 28 Oct with establishment irrigation applied to all plots on 31 Oct, the effective date of sowing. Irrigations were applied by perfo to the irrigated treatments only on 28 Nov, 15 Dec, 24 Dec and 12 Jan. Insecticidal sprays to control Helicoverpa were applied by FDO (see their records). At harvest, 2 outer rows and 0.5 m at the ends of each row were left as borders.

Results are presented in Table 5.4.1. Irrigation slightly delayed flowering and considerably delayed maturity. Irrigation almost tripled total dry matter and grain yield. ICCV 1 was badly affected by fusarium wilt and thus yielded lowest. No genotype significantly out-yielded Annigeri either with or without irrigation.

Table 5.4.1. Effect of irrigation on phenology, total dry matter, grain yield and yield components of five chickpea genotypes, BP 8C, postrainy season, 1986/87.

Irrigation Treatment	Genotype					
	Annigeri	ICCV 1	ICCC 32	ICCC 37	ICCC 42	Mean
			Days to 50% flowering			
Irrig.	44	49	51	42	44	46
Nonirrig.	41	46	50	39	41	43
SE			±0.33 (±0.28)[1]			±0.22*
Mean	42	47	50	41	42	
SE			±0.20**			
			Days to maturity			
Irrig.	96	101	101	94	95	97
Nonirrig.	80	91	92	80	77	84
SE			±0.57** (±0.55)			±0.29**
Mean	88	96	96	87	86	
SE			±0.39**			
			Total dry matter (kg/ha)			
Irrig.	4944	2882	4920	4476	4675	4379
Nonirrig.	1614	1270	1684	1486	1399	1491
SE			±204.0** (±177.6)			±128.0**
Mean	3279	2076	3302	2981	3037	
SE			±125.6**			
			Grain yield (kg/ha)			
Irrig.	2390	645	1969	2255	2354	1922
Nonirrig.	861	450	637	782	767	700
SE			±85.6** (±89.3)			±30.6**
Mean	1625	547	1303	1519	1560	
SE			±63.2**			

Contd...

Table 5.4.1 Contd...

Irrigation Treatment	Genotype					
	Annigeri	ICCV 1	ICCC 32	ICCC 37	ICCC 42	Mean
			Harvest index (%)			
Irrig.	48.5	21.7	40.3	50.6	50.6	42.3
Nonirrig.	53.2	35.2	37.9	52.8	54.9	46.8
SE			±1.81** (±1.59)			±1.12
Mean	50.9	28.4	38.9	51.7	52.8	
SE			±1.12			
			Pods (filled)/Plant			
Irrig.	40.4	31.8	38.4	36.5	30.5	35.5
Nonirrig.	16.7	12.9	11.5	17.0	11.6	13.9
SE			±3.67 (±3.99)			±0.82**
Mean	28.5	22.3	24.9	26.7	21.0	
SE			±2.82			
			Seeds/pod			
Irrig.	1.28	1.15	1.22	1.28	1.17	1.22
Nonirrig.	1.19	1.14	1.06	1.15	1.18	1.14
SE			±0.032 (±0.033)			±0.012
Mean	1.23	1.15	1.14	1.21	1.17	
SE			±0.023			
			100 Seed weight (g)			
Irrig.	16.1	10.9	14.7	16.0	22.2	16.0
Nonirrig.	15.1	13.8	16.3	15.6	21.4	16.4
SE			±0.39** (±0.36)			±0.21
Mean	15.6	12.3	15.5	15.8	21.8	
SE			±0.26**			

1. SE in parentheses are for comparison of genotypes within an irrigation.

6. C-112(85)IC Detection and evaluation of genetic variation in symbiotic nitrogen fixation in chickpea

6.1 Objectives

a) To determine the scope for genetic improvement of symbiotic nitrogen fixation in chickpea.

b) To identify plant and rhizobial germplasm which result in improved symbioses.

c) To measure genotype differences in the residual effect of nitrogen fixation by chickpea by subsequent crops.

6.2 PA 85/20 Effect of high and low N_2-fixing chickpea lines on crop productivity in a Vertisol (OPR)

Introduction

This trial was started in 1984/85 with the objective of recording genotypic differences in high (K 850) and average (Annigeri) nodulating and N_2-fixing lines on grain yield, dry matter, and N-uptake of chickpea and that of a subsequent sorghum crop. More details on this trial are given in the Chickpea Agronomy Progress Report No. 1 pp 107-112. The same trial was repeated in 1986/87 without any change. Therefore in this report we would largely discuss the results of year 1986/87 only. Materials and Methods wherever different from last year have only been reported here.

Materials and Methods

Six treatments in the postrainy season 1986/87 in 6 x 6 Latin Square design were K 850 (high nodulating line) K 850 + 20 kg N ha^{-1}, Annigeri (low nodulating line), Annigeri + 20 kg N ha^{-1}, Safflower, and Fallow; and were same as in the two earlier years. Sowing was done on 23 Oct. 1986 in 30 x 10 cm spacing after rotovating on a flat bed. Soil chemical properties measured at sowing are given in Table 1. A post-sowing perfo-irrigation equivalent to about 50 mm rain was provided on 29 Oct. 1986.

Plants from a 1 m x 90 cm area were removed for plant growth and nodulation observations at 47 DAS. Chickpea plots were harvested at 110 DAS and safflower at 119 DAS.

In the rainy season, 1987, sorghum (CSH 6) was sown on 27 June 1987 in 60 cm rows using a J.D. Planter. Thinning was done to 60 x 10 cm spacing within 15 days after sowing. The crop was raised as rainfed. A total of 120 mm rain fell between 1 May and 27 June when sorghum was sown and 352 mm after sowing (on 7 Sep 1987) of sorghum. Soil moisture measured up to 90 cm depth was similar in all treatment plots. Sorghum was harvested at 72 DAS. During this period it received two weedings, and two sprays against shoot fly and stem borer at different plant growth stages.

Results and Discussion

Soil chemical analysis before sowing chickpea is given in Table 6.2.1. It seems that the high nodule mass of K 850 resulted in improved soil microbial activity as suggested by the presence of higher chickpea rhizobial population in K 850 + N plots than the Annigeri plots (Table 6.2.1). K 850 + N plots had maximum (3.2×10^6 g^{-1} soil) while Fallow plots had minimum population (3.2×10^5 g^{-1} soil) of chickpea rhizobia. As in the earlier two years K 850 formed significantly higher nodule number and had higher nodule mass compared to Annigeri (Table 6.2.2). At 47 DAS, K 850 also had significantly more acetylene reduction activity per plant as well as more specific activity g^{-1} dry nodule mass than Annigeri both with or without 20 kg N ha^{-1}. Significant superiority of K 850 for nodule no. and mass was also recorded at 74 DAS. But the shoot mass of Annigeri was superior to that of K 850, perhaps due to its better adaptability to this environment.

At about 70 DAS several wilt sick patches of plants were seen in K 850 plots. Annigeri being a tolerant line was not affected as much as K 850 but stray dead plants were noticed in Annigeri as well. This resulted in generally lower yield of K 850 than that of Annigeri (Table 6.2.3). K 850 is known to be a late wilting genotype and we noticed wilted plants with pods and there was no scope of any possible compensation effect at this stage due to plasticity trait of chickpea. At final harvest plant count in K 850 plots was significantly lower than those of Annigeri but it was still not too low. The count includes diseased plants as well because of difficulties in separating these from normal plants at the final harvest.

The seed-N concentration of K 850 was 15-18% superior than those of Annigeri seeds but due to low seed yield of K 850 the total N-uptake by K 850 +N treatment remained 4% lower than that of Annigeri +N plots. On the basis of N-uptake at 71 DAS K 850 accumulated 13% more N than the Annigeri plots (Table 6.2.3).

Yield and dry matter of sorghum, like in earlier two years was not significantly different among all chickpea treatment plots. Safflower plots, however, produced lowest dry matter and grain yield while the yield of Fallow plots was only marginally lower than the K 850 + N plots. K 850 plots produced maximum dry matter (2310 kg ha^{-1}) and K 850 + N plots produced maximum grain yield (Table 6.2.4).

Table 6.2.1. Soil chemical analysis before sowing chickpea in the trial PA 85/20, Vertisol, postrainy season 1986/87, ICRISAT Center.

Treatment	pH	EC (dSm^{-2})	Available P ($mg\ kg^{-1}$ soil)	Organic carbon (%)	Nitrogen ($mg\ kg^{-1}$ soil)			No. of rhizobia (log MPN g^{-1} soil)
					Total	NO_3-N	NH_4-N	
Fallow	8.1	0.24	7	1.3	485	2.0	7.2	4.6
K 850 + 20 kg N	8.1	0.23	6	1.1	499	2.5	8.4	5.5
Annigeri + 20 kg N	8.1	0.26	7	1.4	508	2.1	8.0	5.2
K 850	8.2	0.21	7	1.1	495	1.8	7.2	5.2
Annigeri	8.2	0.22	7	1.2	508	2.0	7.8	4.8
Saffower	8.1	0.23	8	1.3	506	2.0	9.2	5.1
SE	±0.06	±0.03	±1.6	±0.28	±21.4	±0.56	±3.0	±0.21
F - test	*	NS	NS	NS	NS	NS	NS	*
CV%	0.7	13	23	23	4	23	37	10

Table 6.2.2. Plant growth, nodulation and N_2-fixation of chickpea and safflower at 47 DAS, BP 2C, postrainy season 1986/87, ICRISAT Center

Treatment	At 47 DAS					At 79 DAS				
	Nodule no. plant^{-1}	Nodule dry mass (mg plant^{-1})	Shoot dry mass (g plant^{-1})	Acetylene reduction activity: uM pl^{-1} h^{-1}	Acetylene reduction activity: uM g^{-1} dry nod h^{-1}	Nodule no. m^{-2}	Nodule dry mass (g m^{-2})	Nodule no. plant^{-1}	Nodule mass (mg plant^{-1})	Shoot dry mass (g m^{-2})
Fallow	0	0	0	0	0	0	0	0	0	0
K 850 + 20 kg N	61	175	2.4	3.59	19.9	1060	3.7	36	131	197
Annigeri + 20 kg N	27	63	2.5	0.57	9.3	453	0.7	14	21	255
K 850	56	173	1.4	4.79	27.6	1023	5.0	36	171	166
Annigeri	29	69	1.5	0.93	13.8	602	0.8	20	26	174
Safflower	0	0	0.5	0.04	0.3	0	0	0	0	46
SE	±4.1	±9.9	±0.14	±0.397	±2.10	±59.3	±0.28	±2.0	±12.2	±9.2
F - test	***	***	***	***	***	***	***	***	***	***
CV%	35	31	25	59	44	28	41	19	34	16

Table 6.2.3. Total dry matter grain yield, plant stand, seed N%, and N-uptake of chickpea and safflower grown on a Vertisol, postrainy season 1986-87 (area harvested 225.5 m^2 to 42.0 m^2).

Treatment	Plant stand (m^{-2})	Total dry matter[1] (kg ha^{-1})	Grain yield[1] (kg ha^{-1})	Seed-N[2] (%)	N-uptake[2] through seeds (kg ha^{-1})	N-uptake by crop at at 71 DAS (kg N ha^{-1})	Shoot N% at 71 DAS
K 850 + 20 kg N	25	1810 (2450)	970 (1310)	3.3	32	53.8	2.8
Annigeri + 20 kg N	30	1970 (2220)	1230 (1390)	2.9	36	56.6	2.2
K 850	25	1710 (2340)	930 (1280)	3.1	29	49.7	3.0
Annigeri	29	1820 (2080)	1160 (1330)	2.6	30	43.7	2.5
Safflower	25	560 (750)	110 (150)	NA	NA	7.2	1.6
SE	±1.1	±76 (145)	±49 (85)	±0.09	±3.9	±2.26	±0.11
F test	**	** (**)	** (**)	**	NS	**	**
CV%	10	12 (18)	12 (19)	3	12	16	13
SE[2]	±1.13	±71 (149)	±43 (92)				
F test[2]	**	NS (NS)	** (NS)				
CV%[2]	10	10 (16)	10 (17)				

1. Data was analysed after eliminating the harvest material from wilt affected patches. Data in parentheses represent the value adjusted for optimum population of plant m^{-2}

2. Statistical analysis done after eliminating data on safflower

Na = Not analysed

Table 6.2.4. Dry shoot mass, grain yield, 1000 seed weight (g) grain N% and N-uptake of sorghum, BP 2C, rainy season 1987, (harvest area, 38.4 m^2).

Treatments in post rainy season	Dry mass (kg ha^{-1}) thinned sorghum at 12 DAS	Weed mass (kg ha^{-1}) at 19 DAS	Days to: 50% flower-ing	Days to: Matu-rity	Number plants m^2	Dry shoot mass (kg ha^{-1})	Grain yield (kg ha^{-1})	100 seed mass (g)
Fallow	45	41	60	95	12	2280	1430	23
K 850 + N	42	37	60	95	13	1990	1530	25
Annigeri + N	40	33	59	95	12	2160	1240	23
K 850	41	24	60	95	13	2310	1190	25
Annigeri	38	29	59	95	12	1850	940	24
Safflower	33	18	61	97	11	1570	480	23
SE	±6.1	±16.2	±0.2	±0.3	±0.8	±261	±300	±0.6
F-test	NS	NS	**	**	NS	**	**	NS
CV%	16	53	1	1	7	13	26	6

6.3 PA 85/27 Evaluation of wilt resistant lines for nodulation (OPR)

Introduction

This trial was started in 1985/86 (see Chickpea Agronomy, Progress Report No.1. pages 118-119) but repeated in the postrainy season of 1986/87 because of the problem of chickpea stunt in 1985/86. The major objective of the trial was to identify a wilt resistant chickpea line that may nodulate at par with K 850.

Materials and Methods

Fourteen wilt resistant lines and 2 check lines Annigeri (ICC 4918) and K 850 (ICC 5003) were sown in randomised block design with four replications on a low-nitrogen Vertisol field BP2C having 60 cm ridges on 28 October 1986 in 4 m x 4 rows plots at 30 x 10 cm spacing. A light irrigation was provided on 29 October 1986. A plant growth and nodulation observation was made at 48 DAS on a sample of 6 plants per plot. All the lines were finally harvested at 100 DAS, except ICC 12258 and ICC 12275 that matured late and were harvested at 108 DAS and 116 DAS respectively.

Results and Discussion

All the lines grew well until harvest on the post-sowing irrigation provided to ensure good nodulation. Nodulation observation at 48 DAS suggested that three lines ranking highest (K 850, ICC 11313, and ICC 12234) and lowest (ICC 12275, ICC 12255, and ICC 11314) were same in both the years. Annigeri ranked 13th in 1985/86 and 10th in 1986/87 (Table 6.3.1). Four lines that ranked very different than last year were ICC 12246, 5th in 1985/86 and 13th in 1986/87, ICC 12258 6th and 9th, ICC 12259 12th and 7th, and ICC 12272 9th and 4th. Differences in soil-nitrogen status and interactions due to chickpea stunt that occurred in 1985/86 may be some of the reasons for such a shift. All other lines ranked within a difference of '2 ranks' from the previous year.

Two of the three highest nodulating lines K 850 and ICC 11313 also produced highest, biomass, viz. 2.55 and 2.63 t ha^{-1} respectively. The other lines producing about 2.5 t ha^{-1} were ICC 12244, ICC 12245, and ICC 12256. The lines producing about 1.4 t ha^{-1} of grains were ICC 11313, ICC 12244, ICC 12246, ICC 12256, Annigeri and K 850 (Table 6.3.1). ICC 11313 thus nodulated similarly to K 850 and produced at par Annigeri and K 850 and may be used to replace K 850 for some trials. It may be worthwhile to have detailed nodulation observations on ICC 11313 in future studies.

Table 6.3.1. Plant growth and nodulation of 48 days old wilt resistant chickpea lines and their yield, Vertisol (BP 2C), postrainy season 1986/87.

Genotype	Nodule no. plant^{-1} (Rank)	Dry matter (t ha^{-1})	Grain yield (t ha^{-1})
ICC 11313	46 (3)	2.63	1.38
ICC 11314	26 (13)	2.40	1.22
ICC 11316	39 (6)	2.14	1.07
ICC 12234	51 (1)	2.33	1.31
ICC 12236	28 (11)	2.42	1.29
ICC 12244	42 (5)	2.57	1.44
ICC 12245	35 (7)	2.46	1.33
ICC 12246	26 (13)	2.40	1.39
ICC 12255	23 (15)	2.41	1.34
ICC 12256	28 (11)	2.52	1.46
ICC 12258	34 (9)	2.17	0.98
ICC 12259	35 (7)	2.36	1.27
ICC 12272	45 (4)	2.22	1.27
ICC 12275	19 (16)	1.76	0.51
Annigeri	30 (10)	2.23	1.42
K 850	51 (1)	2.55	1.38
SE		±0.247	±0.085
F - test	***	***	***
CV %	16	13	14

PA 86/47 Test of suitability of non-nodulating chickpea mutant as a non N_2-fixing control (OPR, NPS)

Introduction

We recently acquired a non-nodulating mutant (PM 233) of ICC 640 from Dr. T.M. Davis of USA. In addition, a spontaneous non-nodulating (Nod$^-$) mutant (ICC 435M) of ICC 435 was identified at ICRISAT Center in the postrainy season of 1985/86. An ideal non-fixing control in N2-fixation studies should be similar to the test plant in growth duration, growth rate, flowering, rooting depth, etc. Therefore, a non-nodulating line of a given legume is a preferred non N_2-fixing control over a non-leguminous crop. This trial was planned to study such aspects of the two mutants and assess their suitability for use as appropriate controls plants.

Materials and Methods

Two chickpea Nod$^-$ lines PM 233 and ICC 435M their parents ICC 640 and ICC 435, respectively, along with other four test lines ICC 4918 (Annigeri), ICC 5003 (K 850), ICC 4948 (G 130), and ICC 4973 (L 550) were grown as subplots on a Vertisol field BP 2C in plots of 5m x 1.2 m. Four nitrogen levels 0, 100, 200 and 400 kg ha^{-1}, applied as urea, formed main plot treatments of the split plot design with four replications. Sowing was done on 27 October 1986 in 30 x 10 cm spacing followed by a sprinkler irrigation of about 30 mm on 29 October 1986. Twenty-five days before sowing chickpea, the appropriate fertilizer levels were placed about 10 cm below the intended plant rows, followed by a sprinkler irrigation of about 22 mm soon after application and another after 8 days interval. This was done to ensure distribution of fertilizer in the soil profile and to prevent possible toxic effects on the growth of chickpea.

Slurry of one inoculant packet (70g) of Rhizobium strain IC 59 was prepared in methyl cellulose (a standard procedure) and coated on to 4-5 kg course (1-3 mm) sand. The coated sand was dried in the shade and evenly spread on the trial area of 50 m x 30 m at the time of disc-ploughing.

The top 15 cm soil profile, of the main (nitrogen) treatment plots was sampled at sowing to determine soil properties for site characterization. Soil sampling at six different soil depths - 0-15, 15-30, 30-45, 45-60, 60-90, 90-120 cm - was done in plant rows where urea was applied before sowing.

Plant growth and nodulation observations were made on a 60 x 30 cm area from each plot at 17, 31, 50, and 70 DAS. Roots at 18 and 75 days were collected from a 0.6 x 0.3 m area (2 rows 30 cm long) at various depths 0-15, 15-30, 30-45, 45-60, 60-90, 90-120 by soaking the excavated soil over-night and sieving it. The root length of the collected root samples was measured using a Comair Root Length Scanner from Commonwealth Aircraft Corporation Ltd., Melbourne, Australia. Fresh and/or dry weight of roots was also determined.

Routine observations on flowering and maturity were taken. The experiment was harvested between 92 and 117 days after sowing.

At 29 DAS we noticed Fe deficiency symptoms on leaves of long duration genotypes that seemed to be associated with the level of applied N at sowing. Therefore at 40 DAS when the symptoms were at its peak we sampled leaves of PM 233, ICC 640, ICC 435, and G 130 from all the four N-levels and four replications to measure zinc, ferrous iron and total iron. All replicate plots of the same four genotypes at two N-levels (0 and 400 kg N ha^{-1}) were also sampled to determine nitrate reductase. The top 3 open leaves along with growing points of 30 plants per plot representing the degree of chlorosis in the plot were sampled and pooled in a polythene bag, placed in an ice box, and brought in lab for nitrate reductase measurement using the method of Jaworski (1971). For chemical analysis, the leaves were washed in water, swab cleaned, cut into pieces and one g per plot was used for extraction and determination of iron and zinc.

Results and Discussion

The soil pH, EC (dS m^{-1}), organic carbon (%), available-P and total N (mg kg^{-1} soil) in the top 15 cm profile did not differ significantly across nitrogen treatments. The NH_4-N and NO_3-N level, however, increased with the increasing level of urea application (Table 6.4.1). The NO_3-N + NH_4-N level recorded in the 100 and 200 kg N ha^{-1} applied plots was similar to the levels recorded in the past in some Vertisol fields at ICRISAT Center and at ICRISAT Cooperative Sub-center, Hisar (Tables 6.4.2, 6.4.3, 6.4.4 and Appendix I). The applied-N levels were very high for chickpea. But our main objective of using such levels were to provide sufficient N to match or even exceed the soil-N levels found in some Vertisol fields at the Center. These objectives were obviously achieved. There were no symptoms of toxicity even at the highest level of 400 kg N ha^{-1} applied as urea 25 days before sowing. This method of N-application allowed growing of chickpea on residual soil moisture without any further irrigation, except at sowing.

Chickpea plants normally draw most of their water and nutrients from the top 60 cm soil profile. The average concentration of available-N present in the top 60 cm was therefore considered as a better indicator of N available to chickpea than the nitrogen levels applied in this study. This seems most appropriate because one may add the same nitrogen levels to a different field but obtain quite different resultant available-N values depending on the inherent soil-N level, soil buffering capacity, etc. The available-N levels (mg kg^{-1} soil) obtained with different doses of fertilizer (kg N ha^{-1}) applied in this study were 8 with control, 15 with 100, 24 with 200, and 37 with 400. Thus we did not obtain a linear relationship between the increment of applied-N level and the resultant available-N in the soil. However, we established four soil profiles with different N-levels.

Jaworski, E.G. 1971. Nitrate reductase assay in intact plant tissues. Biochem. Biophys. Res. Commun. 43: 1274-1279.

Available-N in the soil increased with increasing level of N-application and this reduced both nodule number and mass per plant (Tables 6.4.5-6.4.10, Fig. 6.4.1). Maximum reduction occurred at the first N-level, i.e. when available-N in top 60 cm profile increased from 8 to 15 (mg kg^{-1} soil), or when it increased from 9.7 to 20.1 mg kg^{-1} soil in the top 15 cm profile which may be more relevant for early nodule formation events (Tables 6.4.2, 6.4.3). Available soil-N levels of 20 mg kg^{-1} soil and more are not uncommon at research stations (Appendix-1).

The Nod^{-} line PM 233 was generally free of nodules whenever dug during the season at 17, 31, 50 and 71 DAS. Nodulated plants were encountered only occasionally; these may be contaminants. Few plants had a callus type of growth instead of a normal nodule, as described on pages 120-124 of *Chickpea Agronomy Progress Report No.1*. All the other seven lines under test nodulated normally on the 0-N plots. As expected, ICC 5003 (K 850) nodulated best, followed by ICC435. The other five lines generally nodulated similarly, but much less than ICC 5003 and were not different statistically (Tables 6.4.5-6.4.10)

Plant growth substantially improved with increase in available-N causing maximum improvement at first and this improvement ranged from 19 to 94% over the control plots at different plant growth stages. Generally there was no improvement after the third level of 24 mg N kg^{-1} soil and some lines showed a decline at the fourth level (37 mg kg^{-1} soil). The plant growth of Nod^{-} line PM233 and its parent ICC640 on control plots was generally similar up to 50 DAS but at 71 DAS ICC 640 was about 38% superior to PM 233 (Tables 6.4.11-6.4.14, Fig. 6.4.2).

Brown margins on old leaves of PM 233 in control plots were observed at 46 DAS. These became intense subsequently and progressively advanced to upper leaves. Such symptoms were absent on N-fed plants and on plants of other genotypes, even in control plots.

While digging for nodules, the easily excessible roots in the top 15-20 cm profile were also collected. It was interesting to record significant differences in dry root mass due to nitrogen level and due to genotypes. A 10% to 43% increase was noticed in root mass at different stages from 8 to 15 mg N level. At higher levels of 24 mg and 37 mg there was a marginal decrease over the root mass recorded at 15 mg (Tables 6.4.15- 6.4.18). This decrease seemed largely due to the fact that abundant available-N was in the vicinity of the main roots and the plants perhaps did not require further root proliferation to fulfil its N-needs. Reduced plant growth in some genotypes perhaps suggests a toxicity effect, a hidden one, as we did not see any apparent toxicity symptoms. Alternatively, it may be due to the expected interaction of nitrogen with other soil nutrients as explained above for iron and zinc. At high-N levels the pattern of root length density was also different than at low-N (Table 6.4.19).

Data on shoot N% measured at four different stages of plant growth revealed interesting insights, particularly about the Nod^{-} line PM 233 which generally had lowest N% than the rest of the chickpea lines when grown on low-N plots. It was only marginally lower than its parent ICC 640 when soil-N was 15 mg kg^{-1} soil and was generally better at soil-N level 24 mg kg^{-1} and higher. These differences were generally statistically significant (Table 6.4.20-6.4.23, Fig. 6.4.3). Interaction between soil N-level and genotypes were invariably nonsignificant. The trend for N-uptake was similar to shoot N% (Tables 6.4.24-6.4.27, Fig. 6.4.4).

As the plants grew, the mean shoot N% decreased from 4.7% at 17 DAS to 3.2% at 71 DAS even in the N-sufficient plots. The reduction was substantial from 50 DAS to 71 DAS, obviously suggesting reduced N-uptake from soil particularly after 50 DAS (Tables 6.4.20-6.4.23, Fig. 6.4.3). Thus the growing tissue seems to meet part of its N-needs through N-translocation from the older leaves when grown in N-limiting and even in N-sufficient conditions. Thus the tissue-N concentration in growing leaves may not be a good indicator of the degree of N_2-fixation except when the differences are large.

The Nod^- line PM233 when supplied with nitrogen grew similar to its parent line ICC 640 and had similar tissue N% and N-uptake pattern (Fig. 6.4.5). Both were, however, generally different for nodulation and rooting pattern and extent (Tables 6.4.15-6.4.19). As expected, PM 233 did not form nodules but generally formed more root mass and root length density than ICC 640 (Fig. 6.4.6, Table 6.4.19). This seems to be a need-based phenomenon. Absence of nodules on PM 233 may be forcing the plants to extend its roots faster and more intricately into the soil volume than the nodulated line ICC 640. But this may not be a negative point on its use as a reference plant in ^{15}N studies.

The nodulation pattern of the two familiar chickpea lines Annigeri (ICC 4918) a normal nodulator and K850 (ICC 5003) a high nodulator at the low-N (8 mg) level, was as usual and that of an ICRISAT's released variety ICCC 37 close to ICC 4918 (Fig. 6.4.7). Formation and development of nodules at 15 mg and above reduced greatly (Tables 6.4.5-6.4.10). The nodule mass at 24 mg kg^{-1}N was generally 4 to 20 fold, and the nodule no. 2 to 3-fold, less than that at 8 mg kg^{-1}N (Tables 6.4.5-6.4.10, Fig. 6.4.8). Thus the early processes of nodule formation are not as sensitive to soil-N levels as the processes involved in nodule development.

The total iron, ferrous iron, and zinc measured at 40 DAS in growing tips + the top three open leaves generated interesting information. Neither ferrous iron nor total iron was affected by available-N level. Iron content differed significantly across genotypes and was lowest in ICC 640 and highest in ICC 435 (Tables 6.4.28, 6.4.29). This, however, did not match well with the visual observations where ICC 4948 and ICC 435 showed maximum iron deficiency symptoms. This suggests that the threshold level of iron in genotypes like ICC 435 is higher than that of those like ICC 640. The visually intense chlorosis seen in ICC 435 seems to match well with a sharp decline (mean 16-22%) in total ferrous iron at 15 mg kg^{-1}N. The quantities increased at 24 mg kg^{-1}N but decreased again at 37 mg kg^{-1}N. Although these fluctuations with N-level deserve further study it is certain that N-application influences the appearance of chlorotic symptoms that seems to be associated with the tissue iron content.

The data on tissue zinc concentration showed a trend similar to iron. On a mean basis the tissue Zn showed a reduction of 17% from 8 to 15 mg kg^{-1}N (Table 6.4.30). This, however, raises the query as to whether the chlorotic symptoms are due to iron or zinc. Like iron, the lowest quantities were in ICC 640 but the highest in ICC 4948, the latter showing the highest degree of chlorosis along with ICC 435 that was the next highest in tissue zinc concentration.

Nitrate reductase activity (nmoles NO_2^{-1} $h^{-1}g^{-1}$ fresh leaves) measured in the same four genotypes increased from 2583 units at 8 mg kg^{-1}N to 3709 units at 37 mg kg^{-1}N level across genotypes (Table 6.4.30). Genotypes also differed significantly and PM 233 had the highest activity at 8 mg kg^{-1}N. At 37 mg kg^{-1}N, where all genotypes practically did not nodulate, the Nod^- line PM 233 and its parent ICC640, both short duration lines, had highest activity while the long duration lines ICC 435 and ICC 4948 had practically half the activity of that of the former two (Table 6.4.31). It seems worthwhile to explore if Fe, Zn and NO_3- reductase are really associated with maturity duration.

The plant stand at maturity ranged from 26 to 35 plants m^{-2} (Table 6.4.31). Although the mean genotypic differences were significant it may not be of consequence because wherever relevant most plants died before 30 DAS. Because of substantial appearance of wilt in plots of ICC435M, it was replaced by ICCC 37 at 15 days after sowing. The delay in sowing of ICCC 37 was compensated by its delayed harvest and an additional light watering with rose cans soon after sowing.

Both genotypic and N-level differences were significant both for total dry matter and grain yield. Interactions were, however, significant only for grain yield (Table 6.4.33, 6.4.34). The significantly increased dry matter and grain yield was recorded when available-N increased from 8 to 15 mg kg^{-1}N. There was no further significant increase with further incremental levels. The long duration genotypes such as ICC 4948, ICC 4973 and ICC435 generally produced lowest dry matter and grain yield apparently because of low adaptability of these lines at 17°N lattitude. Among the rest of the short- and medium-duration lines the Nod^- line PM 233 produced least and Annigeri, the adapted line, produced most dry matter and grains. Even at 8 mg kg^{-1}N, PM 233 could produce 2.18 t ha^{-1} of dry matter and 1.05 t ha^{-1} of grains. This strongly suggests its excellent N-scavenging capacity and with N-application it generally yielded at par with its nodulated parent (Tables 6.4.33, 6.4.34).

At 8 mg kg^{-1}N the nodulated genotypes produced 15 to 27% lower dry matter and 6 to 31% lower grains than at the 15 mg kg^{-1} N-level. This apparently is the nitrogen effect and is generally taken as potential of improvement in N_2-fixation. But it is debatable. Nodulation data suggests that it cannot be interpretted so simply. Nodulation in this trial was best at 8 mg and with N-application (or with increase in availabe-N) it reduced greatly at next high level and almost diminished at 24 mg kg^{-1}N (Tables 6.4.5-6.4.10). N_2-fixation, although not measured, can be expected at its maximum at 8 mg kg^{-1}. This suggests that symbiotic plants, being self regulatory and largely self-dependant for their nitrogen needs, are highly unlikely to produce higher than fully N-fed plants. An interaction is, however, expected. Yield improvement due to improvement in BNF in legumes can be expected but not to the level of fully N-fed plants.

Though we did not record any significantly increased dry matter and grain yield at N-level greater than 15 mg, we did record significantly improved seed N% (Fig. 6.4.9) and seed N yield (or seed protein yield) at every successive level up to 37 mg $kg^{-1}N$ level in most genotypes. Even the genotypes were significantly different for these traits. Available-N level and genotype interactions were significant only for N-yield (or protein yield) (Table 6.4.35, 6.4.36).

At 8 mg $kg^{-1}N$, the Nod^- line PM 233 had lowest N% and N-yield. ICC 4918, the normal nodulating line, had the next higher value with 15% protein but had highest N-yield (protein harvest = 89 kg ha^{-1}) obviously due to highest seed yield. We have generally seen this happening with ICC 4918 despite the fact that it generally nodulates about half as well as ICC 5003 (Tables 6.4.5-6.4.10) that had 16.8% protein (second highest) and 88 kg ha^{-1} protein yield (at par ICC 4918). With available-N higher than 8 mg $kg^{-1}N$ the seed N% and N-yield of the Nod^- line PM 233 was at par its nodulated parent ICC 640.

From these data sets it seems that the Nod^- line PM 233 is a very good control plants for N_2-fixation studies, has growth rates and yield levels similar to its nodulated parent at soil-N levels of most Vertisol fields at ICRISAT Center.

Some thoughts on possible follow up:

1. Study N_2-fixation pattern over time as affected by chlorotic symptoms.

2. Would NH_4^+ and NO_3^- fed plants behave differently for chlorotic symptoms in sand versus soil culture.

3. Long-duration genotypes where induction of NO_3 reductase is at par with short-duration and gets substantially enhanced with N-application may be searched. These may be the ones with better plant growth vigour.

4. Genotypes (short to long duration) with low tissue concentration of Fe and zinc are highly likely to be the ones which would not show chlorosis where sensitive ones (with high tissue concentration of Fe^{++} and Zn^{++}) would show. This relationship should be established on a range of selected genotypes. Such a study should include PM 233, ICC 435, ICC 435M, -640, -4918 (Annigeri), -4918M, -4935 (C235), -4948 (G130), -4954 (H208), -4993 (Rabat), and -4993M.

Table 6.4.1. Soil chemical properties of top 15 cm profile of the Vertisol where the trial PA 86/47 was conducted with four different levels of nitrogen, ICRISAT Center, postrainy season 1986/87.

Fertilizer-N level	pH	EC ($dS\ m^{-1}$)	NO_3-N ($mg\ kg^{-1}$ soil)	NH_4-N ($mg\ kg^{-1}$ soil)	NO_3-N + NH_4-N ($mg\ kg^{-1}$ soil)	Total N ($mg\ kg^{-1}$ soil)	Olsen-P ($mg\ kg^{-1}$ soil)	Organic carbon (%)
Control	8.2	0.27	6.2	7.6	13.8	543	6.5	1.2
100 kg N	8.0	0.31	15.1	6.0	21.1	526	6.4	1.2
200 kg N	8.0	0.30	16.2	6.9	23.0	539	6.4	1.2
400 kg N	7.9	0.37	38.3	7.9	46.3	552	6.4	1.3
Mean	8.0	0.31	19.0	7.1	26.0	540	6.4	1.2
SE	±0.04	±0.027	±2.77	±0.21	±2.89	±11.2	±0.33	±0.04
F-test	**	NS	***	***	***	NS	NS	NS
CV%	1.1	17.5	29.2	5.9	22.2	4.1	10.3	7.1

Table 6.4.2. Available nitrogen ($NH4^+$-N mg kg^{-1} soil) at different soil depths in a Vertisol supplied with different levels of fertilizer nitrogen (urea), at 29 days after fertilizer application, ICRISAT Center, postrainy season, 1986/87.

Depth (cm)	Fertilizer nitrogen applied kg ha^{-1}				Mean
	0	100	200	400	
0-15	3.8	7.2	11.1	13.8	9.0
15-30	4.1	5.7	12.8	15.3	9.5
30-45	5.4	5.2	12.5	9.8	8.2
45-60	4.2	5.1	9.0	10.4	7.2
60-90	3.9	4.0	6.3	8.5	5.7
90-120	4.2	3.7	4.0	7.5	4.9
SE			±3.59●		±0.97
Mean	4.3	5.1	9.3	10.9	
SE			±3.12		

● SE to compare different levels of depth at same N level is ±1.95

F test: Nitrogen : NS; Depth : **; Nitrogen x depth: NS
CV% : Nitrogen : 84.4; Nitrogen x depth : 52.7

Table 6.4.3. Available nitrogen (NO_3-N, mg kg^{-1} soil) at different soil depths in a Vertisol supplied with different levels of fertiler nitrogen (urea), at 29 days after fertilizer application, ICRISAT Center, postrainy season, 1986/87.

Depth (cm)	Fertilizer nitrogen applied (kg ha^{-1}) 0	100	200	400	Mean
0-15	5.9	12.9	13.3	37.0	17.3
15-30	3.9	9.5	10.7	27.0	12.8
30-45	3.3	7.3	9.9	20.4	10.2
45-60	3.5	6.6	5.8	14.9	7.7
60-90	3.2	5.8	5.8	4.8	4.9
90-120	3.0	2.8	3.7	6.9	4.1
SE		± 3.79●			± 1.39
Mean	3.6	7.5	8.2	18.5	
SE		± 2.82			

SE to compare different levels of depth at same N level is ±2.77.

F test: Nitrogen *; Depth : ***; Nitrogen x depth ***
CV% : Nitrogen 59.3; Nitrogen X Depth : 58.4

Table 6.4.4. Available-N (NO_3-N + NH_4-N, mg kg^{-1} soil) concentration in Vertisol at 29 days after applying four different levels of fertilizer nitrogen, ICRISAT, postrainy season 1986/87.

Genotype	Fertilizer-N applied (kg ha^{-1}) 0	100	200	400	Mean
0-15	9.7	20.1	24.4	50.8	26.2
15-30	8.0	15.2	23.5	42.3	22.3
30-45	8.6	12.5	22.4	30.1	18.4
45-60	7.7	11.7	14.7	25.3	14.9
60-90	7.0	9.8	12.1	13.3	10.5
90-120	7.3	6.5	7.7	14.5	9.0
SE		±2.49●			±1.0
Mean	8.0	12.6	17.5	29.4	
SE		+1.60			

a = SE to compare means of different levels of depth at same N level is ±2.09

F-test : Nitrogen : ***; Depth : ***; Nitrogen x depth : ***
CV% : Nitrogen : 19.0; Nitrogen x depth : 24.8

Table 6.4.5. Effect of different N-levels on nodule no. $plant^{-1}$ (at 17 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	0	0	0	0	0
ICC 640	30	20	16	18	21
Annigeri	21	16	18	13	17
K 850	43	19	12	15	22
ICCC 37	24	12	10	12	14
L 550	24	12	10	12	14
G 130	24	12	10	12	14
ICC 435	24	12	10	12	14
SE[a]		±2.5			±1.1
Mean	24	13	11	12	14
SE		±1.4			

a = SE to compare means of different genotypes at same nitrogen level is ±2.2

F-test: Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : ***
CV% : Nitrogen : 20; Nitrogen x Genotype : 31

Table 6.4.6. Effect of different N-levels on nodule no. $plant^{-1}$ (at 31 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	0	0	0	0	0
ICC 640	32	17	16	11	19
Annigeri	30	17	13	11	18
K 850	39	27	14	9	22
ICCC 37	34	26	17	14	22
L 550	16	27	9	6	15
G 130	29	21	12	9	17
ICC 435	30	22	12	10	18
SE[a]		±3.1			±1.3
Mean	26	20	12	9	16
SE		±1.8			

a = SE to compare means of different genotypes at same nitrogen level is ±2.7

F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype **
CV% : Nitrogen : 21; Nitrogen x Genotype : 31

Table 6.4.7. Effect of different N-levels on nodule mass (mg pl^{-1}) (at 17 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	0	0	0	0	0
ICC 640	18	6	5	7	9
Annigeri	13	6	7	5	8
K 850	17	7	2	3	7
ICCC 37	16	3	4	2	6
L 550	12	6	4	2	6
G 130	8	6	3	3	5
ICC 435	22	8	3	4	9
SE		±1.4[a]			±0.7
Mean	13	5	4	3	6
SE		±0.4			

a = SE to compare means of different genotypes at same nitrogen level is ±1.4

F-test: Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : ***

CV% : Nitrogen : 14; Nitrogen x Genotype : 44

Table 6.4.8. Effect of different N-levels on nodule mass (mg pl^{-1}) (at 31 DAS) of different chickpea genotypes grown on a vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	0	0	0	0	0
ICC 640	38	5	3	2	12
Annigeri	52	10	4	2	17
K 850	67	17	3	2	22
ICCC 37	33	19	5	1	14
L 550	27	9	2	6	11
G 130	27	15	4	1	12
ICC 435	43	10	2	2	14
SE[a]		±6.1			±3.1
Mean	36	11	3	2	13
SE		±2.1			

a = SE to compare means of different genotypes at same nitrogen level is ±6.1

F-test: Nitrogen : ***; Genotype : NS; Nitrogen x Genotype : NS

CV% : Nitrogen : 30; Nitrogen x Genotype : 88

Table 6.4.9. Effect of different N-levels on nodule mass (mg pl^{-1}) at 50 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	0	0	0	0	0
ICC 640	74	9	6	5	23
Annigeri	67	13	8	6	23
K 850	225	37	4	2	67
ICCC 37	106	6	8	3	31
L 550	76	21	5	5	27
G 130	80	20	6	4	27
ICC 435	160	13	8	2	46
SE		$\pm10.8^a$			±5.2
Mean	99	15	5	3	
SE		±4.7			

a = SE to compare means of different genotypes at same nitrogen level is ±10.4

F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : ***

CV% : Nitrogen : 30.8; Nitrogen x Genotype : 67.9

Table 6.4.10. Effect of different N-levels on nodule mass (mg pl^{-1} (at 71 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	0	0	0	0	0
ICC 640	44	26	5	5	20
Annigeri	77	16	6	4	26
K 850	476	155	8	6	161
ICCC 37	78	8	7	1	24
L 550	63	26	9	4	25
G 130	103	16	7	7	33
ICC 435	394	40	19	5	115
SE		$\pm35.2^a$			±16.3
Mean	155	36	8	4	
SE		±17.6			

a = SE to compare means of different genotypes at same nitrogen level is ±32.6

F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : ***

CV% : Nitrogen : 70; Nitrogen x Genotype : 129

Table 6.4.11. Effect of different N-levels on shoot mass (g $plant^{-1}$) (at 17 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil) 8	15	24	37	Mean
PM 233	0.223	0.268	0.289	0.336	0.278
ICC 640	0.240	0.326	0.330	0.355	0.313
Annigeri	0.148	0.187	0.232	0.216	0.196
K 850	0.214	0.251	0.242	0.286	0.248
ICCC 37	0.164	0.209	0.224	0.224	0.205
L 550	0.187	0.220	0.257	0.260	0.231
G 130	0.144	0.178	0.176	0.159	0.164
ICC 435	0.204	0.222	0.216	0.214	0.214
SE		±0.0185[a]			±0.0087
Mean	0.191	0.232	0.246	0.256	
SE		±0.0089			

a = SE to compare means of different genotypes at same nitrogen level is ±0.0174

F-test: Nitrogen : **; Genotype : ***; Nitrogen x Genotypes : NS

CV% : Nitrogen : 8; Nitrogen x Genotype : 15

Table 6.4.12. Effect of different N-levels on shoots mass (g $plant^{-1}$) (at 31 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil) 8	15	24	37	Mean
PM 233	1.0	1.4	1.6	1.5	1.4
ICC 640	1.0	1.8	1.7	1.4	1.4
Annigeri	0.8	1.6	1.2	1.5	1.3
K 850	0.7	1.5	1.8	1.6	1.4
ICCC 37	0.7	1.2	1.2	1.6	1.2
L 550	0.7	1.5	1.2	1.4	1.2
G 130	1.0	1.3	1.2	1.1	1.1
ICC 435	0.9	1.2	1.3	1.1	1.1
SE		±0.15[a]			±0.08
Mean	0.8	1.4	1.4	1.4	
SE		±0.04			

a = SE to compare means of different genotypes at same nitrogen level is ± 0.16

F-test: Nitrogen : ***; Genotype : *; Nitrogen x Genotype : NS

CV% : Nitrogen : 6; Nitrogen x Genotype : 25

Table 6.4.13. Effect of different N-levels on shoot mass (g $plant^{-1}$) at 50 DAS of different chickpea genotypes grown on a vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil) 8	15	24	37	Mean
PM 233	3.6	6.7	6.4	5.6	5.6
ICC 640	3.7	7.2	6.2	6.3	5.8
Annigeri	3.3	5.7	6.2	6.2	5.3
K 850	3.4	4.8	4.8	5.2	4.5
ICCC 37	2.9	4.2	5.2	4.7	4.3
L 550	3.1	4.6	4.9	4.0	4.1
G 130	2.9	4.2	3.7	3.6	3.6
ICC 435	2.5	3.8	3.6	3.4	3.3
SE		±0.41[a]			±0.21
Mean	3.2	5.1	5.1	4.9	
SE		±0.13			

a = SE to compare means of different genotypes at same nitrogen level is ± 0.41
F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : NS
CV% : Nitrogen : 6; Nitrogen x Genotype : 18

Table 6.4.14. Effect of different N-levels on shoot mass (g $plant^{-1}$) at 71 DAS of different chickpea genotypes grown on a vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil) 8	15	24	37	Mean
PM 233	5.6	10.7	12.4	12.6	9.8
ICC 640	7.7	13.4	12.2	12.1	11.4
Annigeri	8.8	12.4	15.4	13.8	12.6
K 850	6.7	10.2	10.4	8.9	9.1
ICCC 37	7.9	13.1	11.8	12.1	11.2
L 550	6.8	8.2	9.9	11.6	9.1
G 130	5.2	8.6	8.3	8.9	7.7
ICC 435	5.1	7.5	6.9	7.6	6.8
SE		±1.06[a]			±0.53
Mean	6.7	10.5	10.9	10.7	
SE		±0.37			

a = SE to compare means of different genotypes at same nitrogen level is ± 1.06
F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : NS
CV% : Nitrogen : 8; Nitrogen x Genotype : 22

Table 6.4.15. Effect of different N-levels on root mass (mg $plant^{-1}$) (at 17 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	31	45	43	28	37
ICC 640	30	40	46	36	38
Annigeri	38	38	39	34	37
K 850	47	55	46	60	52
ICCC 37	42	39	38	44	41
L 550	49	53	49	51	50
G 130	34	39	29	36	35
ICC 435	47	47	44	44	46
SE		± 3.6[a]			± 1.8
Mean	40	44	42	42	
SE		± 1.1			

a = SE to compare means of different genotypes at some nitrogen level is ± 3.7
F-test : Nitrogen : *; Genotype : ***; Nitrogen x Genotype : *
CV% : Nitrogen : 5; Nitrogen x Genotype : 18

Table 6.4.16. Effect of different N-levels on root mass (mg $plant^{-1}$) (at 31 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	101	112	105	103	105
ICC 640	89	132	118	99	110
Annigeri	72	89	75	99	84
K 850	77	89	110	107	96
ICCC 37	64	89	92	113	89
L 550	82	115	93	105	99
G 130	94	101	88	72	89
ICC 435	98	97	100	99	99
SE		± 11.1[a]			± 5.7
Mean	85	103	98	100	
SE		± 3.0			

a = SE to compare means of different genotypes at same nitrogen level is ± 11.4
F-test : Nitrogen : **; Genotype : *; Nitrogen x Genotype : NS
CV% : Nitrogen : 6; Nitrogen x Genotype : 24

Table 6.4.17. Effect of different N-levels on root mass (mg $plant^{-1}$) (at 50 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	301	405	373	348	357
ICC 640	222	440	320	335	329
Annigeri	205	295	304	309	278
K 850	189	253	227	213	221
ICCC 37	208	238	282	262	247
L 550	243	351	324	240	290
G 130	221	292	260	225	249
ICC 435	187	262	255	217	230
SE		± 27.6[a]			± 14.1
Mean	222	317	293	269	
SE		± 8.1			

a = SE to compare means of different genotypes at same nitrogen level is ± 28.3

F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : NS

CV% : Nitrogen : 6; Nitrogen x Genotype : 21

Table 6.4.18. Effect of different N-levels on root mass (mg $plant^{-1}$) (at 71 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	5	15	24	37	
PM 233	369	424	456	247	349
ICC 640	170	416	373	253	303
Annigeri	337	369	373	372	363
K 850	418	599	492	459	492
ICCC 37	321	417	436	374	387
L 550	492	557	488	552	522
G 130	467	572	587	521	537
ICC 435	499	587	503	541	532
SE		± 43.2[a]			± 20.7
Mean	372	493	464	415	
SE		+ 19.2			

a = SE to compare means of different genotypes at same nitrogen level is ± 41.4

F-test : Nitrogen : **; Genotype : ***; Nitrogen x Genotype : NS

CV% : Nitrogen : 9; Nitrogen x Genotype : 19

Table 6.4.19. Root length density (mm cm^{-3}) of two chickpea genotypes at five soil depths at two soil-N levels, postrainy season 1986/87, ICRISAT Center.

Depth cm	Genotypes		Mean	Available-N (mg kg^{-1} soil)	
	PM233	ICC640		8	37
0-15	2.5	2.1	2.3	1.6	3.0
15-30	2.3	1.8	2.1	2.0	2.2
30-60	2.1	1.9	2.0	2.5	1.6
60-90	3.4	1.5	2.4	3.0	1.9
90-120	1.3	0.8	1.0	1.7	0.4
SE	±0.29(0.20)		±0.25	±0.60(0.35)	
Mean	2.3	1.6		2.1	1.8
SE	±0.09			±0.51	

Note: Depth, genotype, nitrogen x depth, cultivar x depth were statistically significantly different and are only tabulated.

F-test: Nitrogen : NS; Depth : *; Genotype : ***
Nitrogen : Depth : *; Genotype x Depth : *;
Nitrogen x Genotype : NS; Nitrogen x Depth x Genotype : NS

Table 6.4.20. Effect of different N-levels on shoot N% (at 17 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	4.2	4.6	5.0	4.7	4.6
ICC 640	4.3	4.9	5.2	5.0	4.9
Annigeri	4.0	4.8	5.0	5.0	4.7
K 850	4.2	4.3	4.9	4.6	4.5
ICCC 37	3.9	5.0	4.8	4.7	4.6
L 550	4.1	4.3	4.9	4.5	4.5
G 130	4.2	4.8	4.9	4.7	4.6
ICC 435	4.1	4.7	4.5	4.5	4.5
SE		± 0.17[a]			± 0.09
Mean	4.1	4.7	4.9	4.7	
SE		± 0.04			

a = SE to compare means of different genotypes at same nitrogen level is ± 0.18

F-test : Nitrogen : ***; Genotype : *; Nitrogen x Genotype : NS
CV% : Nitrogen : 2; Nitrogen x Genotype : 8

Table 6.4.21. Effect of different N-levels on shoot N% (at 31 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	3.7	4.6	5.4	4.8	4.6
ICC 640	4.5	4.9	4.6	4.9	4.8
Annigeri	4.5	5.0	5.3	4.9	4.9
K 850	4.6	4.8	5.2	5.3	4.9
ICCC 37	4.3	4.7	5.0	4.9	4.7
L 550	4.5	4.5	4.9	4.6	4.6
G 130	4.2	4.8	4.9	5.0	4.7
ICC 435	4.1	5.0	4.9	5.0	4.8
SE[a]		± 0.15			± 0.08
Mean	4.3	4.8	5.0	4.9	
SE		± 0.06			

a = SE to compare means of different genotypes at same nitrogen level is ± 0.15
F-test : Nitrogen : ***; Genotype : *; Nitrogen x Genotype : *
CV% : Nitrogen : 3; Nitrogen x Genotype : 6

Table 6.4.22. Effect of different N-levels on shoot N% (at 50 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	3.3	3.9	4.5	4.3	4.0
ICC 640	4.3	4.2	4.4	4.3	4.3
Annigeri	4.0	4.4	4.7	4.6	4.4
K 850	4.4	4.6	4.6	5.0	4.7
ICCC 37	4.1	4.1	4.5	4.7	4.3
L 550	4.0	4.2	4.5	4.6	4.3
G 130	3.9	4.1	4.6	4.6	4.3
ICC 435	3.9	4.6	4.5	4.6	4.4
SE		± 0.15[a]			± 0.07
Mean	4.0	4.3	4.5	4.6	
SE		± 0.06			

a = SE to compare means of different genotypes at same nitrogen level is ± 0.15
F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : NS
CV% : Nitrogen : 3; Nitrogen x Genotype : 7

Table 6.4.23. Effect of different N-levels on shoot N% (at 71 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	1.9	2.6	3.1	3.0	2.6
ICC 640	2.3	2.8	2.8	3.1	2.7
Annigeri	2.6	3.1	2.9	3.2	3.0
K 850	2.9	2.8	3.5	3.4	3.2
ICCC 37	2.3	2.6	3.0	3.1	2.8
L 550	2.5	3.1	3.4	3.4	3.1
G 130	2.7	3.0	3.6	2.8	3.0
ICC 435	2.8	3.3	3.7	3.7	3.4
SE		$\pm$ 0.18[a]			$\pm$ 0.09
Mean	2.5	2.9	3.2	3.2	
SE		$\pm$ 0.05			

a = SE to compare means of different genotypes at same nitrogen level is $\pm$ 0.18

F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : NS

CV% : Nitrogen : 4; Nitrogen x Genotype : 12

Table 6.4.24. Effect of different N-levels on N-uptake (mg $plant^{-1}$) (at 17 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	9	12	15	16	13
ICC 640	10	16	17	18	15
Annigeri	6	9	12	11	9
K 850	9	11	12	13	11
ICCC 37	6	10	11	11	10
L 550	8	10	13	12	10
G 130	6	9	9	7	8
ICC 435	9	11	10	10	10
SE		$\pm$ 1.1[a]			$\pm$ 0.6
Mean	8	11	12	12	
SE		$\pm$ 0.5			

a = SE to compare means of different genotypes at same nitrogen level is $\pm$ 1.1

F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : NS

CV% : Nitrogen : 9; Nitrogen x Genotype : 21

Table 6.4.25. Effect of different N-levels on N-uptake (mg $plant^{-1}$) (at 31 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	36	65	86	71	65
ICC 640	43	87	81	61	68
Annigeri	35	81	65	72	63
K 850	33	73	92	86	71
ICCC 37	28	59	61	80	57
L 550	33	68	60	63	56
G 130	42	60	57	55	54
ICC 435	37	59	65	57	54
SE[a]		± 7.9			± 4.1
Mean	36	69	71	68	
SE		± 2.2			

a = SE to compare means of different genotypes at same nitrogen level is ± 8.1
F-test : Nitrogen : ***; Genotype : *; Nitrogen x Genotype : NS
CV% : Nitrogen : 7; Nitrogen x Genotype : 27

Table 6.4.26. Effect of different N-levels on N-uptake (mg pl^{-1}) (at 50 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	126	263	288	244	230
ICC 640	157	299	271	264	248
Annigeri	130	251	292	283	239
K 850	150	218	224	260	213
ICCC 37	117	176	232	221	187
L 550	123	193	222	185	181
G 130	115	173	173	168	157
ICC 435	100	176	165	155	149
SE		± 20.4[a]			± 10.3
Mean	127	219	234	222	
SE		± 6.7			

a = SE to compare means of different genotypes at same nitrogen level is ± 20.6
F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : NS
CV% : Nitrogen : 7; Nitrogen x Genotype : 21

Table 6.4.27. Effect of different N-levels on N-uptake (mg $plant^{-1}$) (at 71 DAS) of different chickpea genotypes grown on a Vertisol, ICRISAT Center, postrainy season, 1986/87.

Genotype	Nitrogen level (mg kg^{-1} soil)				Mean
	8	15	24	37	
PM 233	103	272	379	311	266
ICC 640	170	370	338	371	312
Annigeri	230	378	453	437	284
K 850	194	289	372	301	289
ICCC 37	187	343	357	378	316
L 550	167	254	329	384	284
G 130	141	256	301	265	241
ICC 435	142	246	253	285	232
SE		± 34.6[a]			± 17.3
Mean	167	301	348	342	
SE		± 12.3			

a = SE to compare means of different genotypes at same nitrogen level is ± 34.6

F-test : Nitrogen : ***; Genotype : ***; Nitrogen x Genotype : NS

CV% : Nitrogen : 9; Nitrogen x Genotype : 24

Table 6.4.28. Effect of N on total iron in the young leaves of 40 day old chickpea, Vertisol, postrainy season 1986/87.

Available-N in top 60 cm profile (mg kg^{-1} soil)	Total iron (ppm)				
	ICC 640	PM 233	ICC 435	G 130	Mean
8	236	270	342	312	290
15	202	221	281	279	245
24	217	216	379	274	272
37	224	253	324	268	265
SE		±24.8[a]			±17.7
Mean	220	240	331	283	
SE		±10.0			

	Nitrogen treatment	Cultivar	Nitrogen treatment x cultivar
F test	NS	**	NS
CV %	13.2	14.9	

a. SE to compare mean of different cultivar at same N treatment is ±20.1

Table 6.4.29. Effect of fertilizer -N on ferros iron in the young leaves of 40 day old chickpea, Vertisol, postrainy season 1986/87.

Available-N in top 60 cm profile (mg kg^{-1} soil)	Total iron (ppm)				
	ICC 640	PM 233	ICC 435	G 130	Mean
8	13.1	14.1	16.2	13.7	14.3
15	12.6	11.1	12.3	8.9	11.2
24	11.2	11.9	17.8	11.4	13.1
37	11.7	12.4	15.4	9.8	12.3
SE		±1.40[a]			±0.72
Mean	12.1	12.4	15.5	11.0	
SE		±0.70			

	Nitrogen application	Cultivar	N x cultivar
F test	NS	**	NS
CV %	11.3	21.9	

a. SE to compare mean of different cultivars at same N treatment is ±1.39

Table 6.4.30. Effect of N on zinc in the young leaves of 40 day old chickpea, Vertisol, postrainy season 1986/87.

Available-N in top 60 cm profile (mg kg^{-1} soil)	Zinc (ppm)				
	ICC 640	PM 233	ICC 435	G 130	Mean
0	66.5	44.5	72.3	82.0	78.8
100	59.5	59.5	67.3	74.5	65.2
200	62.8	58.8	70.8	79.0	67.8
400	60.0	54.0	64.8	71.5	62.6
SE		±3.42[a]			±2.58
Mean	62.2	66.7	68.8	76.7	
SE		±1.30			

	Nitrogen treatment	Cultivar	Nitrogen treatment x cultivar
F test	**	**	**
CV %	7.5	7.6	

a. SE to compare mean of different cultivars at same N treatment is ±2.59

Table 6.4.31. Effect of fertilizer N on nitrate reductase in the young leaves of 40 day old chickpea, Vertisol, postrainy season 1986/87.

Available-N in top 60 cm profile (mg kg^{-1} soil)		Nitrate reductase (n moles NO_2^- h^{-1} g^{-1} fresh leaves)				
		ICC 640	PM 223	ICC 435	G 130	Mean
0		2808	2931	2494	2099	2583
400		5022	4650	2721	2444	3709
	SE		±1051.9[a]			±920.6
	Mean	3915	3790	2608	2272	
	SE		±415.5			

	Nitrogen treatment	Cultivar	N application x cultivar
F test	NS	*	NS
CV %	58.5	37.4	

a. SE to compare mean of different cultivars at same N treatment is ±587.6

Table 6.4.32. Effect of different N-levels on plant stand (m^{-2}) at maturity, chickpea of different genotypes in a Vertisol ICRISAT Center, 1986-87 (area harvested 1.2 to 3.6 sq.m.).

	N application (mg kg^{-1} soil)				
Genotype	8	15	24	37	Mean
ICC 640	28.4	30.8	30.4	29.1	29.7
PM 233	29.2	30.5	29.8	27.8	29.3
ICC 435	24.5	26.1	28.4	25.8	26.2
ICC 37	34.9	34.5	32.6	33.5	33.9
K 850	29.3	30.9	34.4	31.3	31.4
G 130	29.4	28.5	28.6	26.8	28.3
Annigeri	28.7	30.2	30.2	28.1	29.3
L 550	29.8	32.1	31.0	29.7	30.7
SE		±1.45[a]			±0.68
Mean	29.3	30.1	30.7	29.0	
SE		±0.69			

a. SE to compare mean of different genotypes at same nitrogen level is ±1.44.
F test: Nitrogen: NS; Cultivar: **; N x cultivar : NS
CV% : Nitrogen: 4.6; N x cultivar : 9.1

Table 6.4.33. Effect of different N-levels on dry matter yield (tonnes ha^{-1}) of chickpea on a Vertisol, ICRISAT Center, postrainy season 1986/87 (area harvested 1.2 to 3.6 sq.m.).

Genotype	N application (mg kg^{-1} soil)				Mean
	8	15	24	37	
ICC 640	2.90	3.98	3.77	3.92	3.64
PM 233	2.18	3.57	4.12	3.48	3.51
ICC 435	2.54	3.12	3.23	2.87	2.94
ICC 37	2.94	3.73	4.53	4.20	3.85
K 850	3.15	3.78	4.02	3.84	3.70
G 130	2.21	2.81	3.01	3.01	2.76
Annigeri	2.96	3.97	4.41	4.26	3.90
L 550	2.95	3.48	3.51	3.50	3.36
SE		±0.204[a]			±0.103
Mean	2.73	3.55	3.83	3.63	
SE		±0.064			

a. SE to compare means of different genotypes at same nitrogen level is ±0.241
F test: Nitrogen : **; Cultivar : **; N x cultivar : NS
CV% : Nitrogen : 3.7; N x cultivar : 12.0

Table Table 6.4.34. Effect of different N-levels on grain yield (tonnes ha^{-1}) of chickpea on a Vertisol, ICRISAT Center, postrainy season 1986/87 (area harvested 1.2 to 3.6 sq.m.).

Genotype	N application (mg kg^{-1} soil)				Mean
	8	15	24	37	
ICC 640	1.61	2.35	2.27	2.32	2.14
PM 233	1.05	2.21	2.31	1.91	1.87
ICC 435	1.08	1.02	0.77	1.22	1.02
ICC 37	1.76	2.18	2.55	2.44	2.23
K 850	1.80	2.10	2.19	2.07	2.04
G 130	1.03	1.03	1.23	1.15	1.11
Annigeri	1.92	2.41	2.69	2.58	2.40
L 550	1.39	1.60	1.66	1.62	1.57
SE		±0.155[a]			±0.07
Mean	1.45	1.86	1.96	1.91	
SE		±0.064			

a. SE to compare means of different genotypes at same nitrogen level is ±0.151
F test: Nitrogen : **; Cultivar : **; N x cultivar : **
CV% : Nitrogen : 7.1; N x cultivar : 16.8;

Table 6.4.35. Effect of different N-levels on grain protein % (N%* 6.25) of different chickpea genotypes in a Vertisol ICRISAT Center, 1986/87 (area harvested 1.2 to 3.6 sq.m.).

	N application (mg kg^{-1} soil)				
Genotype	8	15	24	37	Mean
ICC 640	17.7	21.0	25.0	26.5	22.5
PM 233	14.2	20.9	25.1	26.3	21.6
ICC 435	16.7	20.8	24.9	25.5	22.0
ICC 37	15.3	18.7	24.4	24.8	20.8
K 850	16.8	21.4	25.4	28.3	23.0
G 130	16.5	20.2	26.1	26.8	22.4
Annigeri	15.0	18.8	20.2	23.7	19.4
L 550	16.4	20.7	23.8	26.8	21.9
SE		±0.73[a]			±0.37
Mean	16.1	20.3	24.4	26.1	
SE		+0.24			

a. SE to compare means of different genotypes at same nitrogen level is ±0.73
F test: Nitrogen : **; Cultivar : **; N x cultivar : NS
CV% : Nitrogen : 2.2; N x cultivar : 6.8

Table 6.4.36. Effect of different N-levels on grain protein yield (kg ha^{-1}) of chickpea genotypes in a Vertisol, ICRISAT Center, 1986/87 (area harvested 1.2 to 3.6 sq.m.).

	N application (mg kg^{-1} soil)				
Genotype	8	15	24	37	Mean
ICC 640	77	154	179	167	144
PM 233	46	118	169	163	124
ICC 435	59	64	64	101	72
ICC 37	79	121	195	204	150
K 850	88	154	187	197	156
G 130	61	68	98	85	78
Annigeri	89	129	155	177	138
L 550	67	103	120	122	103
SE		±12.7[a]			±6.5
Mean	71	114	146	152	
SE		±3.6			

a. SE to compare means of different genotypes at same nitrogen level is ±13.0
F test: Nitrogen : **; Cultivar : **; N x cultivar : **
CV% : Nitrogen : 5.9; N x cultivar : 21.5

Appendix I

Available-N (NO_3-N + NH_4-N) concentration in top 15 cm profile in fields at ICRISAT Center, and ICRISAT Cooperative Subcenters at Hisar and Gwalior vis-a-vis farmers' fields.

Field (1)	Available-N (mg kg^{-1} soil) (2)	Sampling time (3)	Remarks (4)
ICRISAT Center			
BR 4	3.8	June 1985	Soil used for pot trial PA 85/14
BP 9 A	11.6	June 1985	Top 30 cm profile
BP 14 C	7.9	June 1985	"
BIL 2 C	8.8 - 37.9	12.6.85	
BP 2 C	16.9 - 27.3	12.6.85	
BIL 5 A	19.9 - 25.3	June 1986	
BIL 5 B	14.9	June 1986	
BIL 5 C	17.9	June 1986	
BIL 5 D	18.2 - 18.9	June 1986	
BIL 6 C	12.2	June 1986	
BIL 6 D	22.1	June 1986	
BIL 6 E	17.6 - 19.7	June 1986	
BIL 6 H	21.2	June 1986	
BM 14 A	13.9	June 1986	
BM 14 B	12.8	June 1986	
BM 14 E	13.6	June 1986	
BIL 6 E	19.8 - 35.5	11.11.1986	
BIL 6 H	24.0 - 31.6	11.11.1986	
BP 5	20.7	Oct 1990	About one week after sowing chickpea
BP 6	23.4	Oct 1990	"
BP 7	22.0	Oct 1990	"
BP 14 A	42.1	Oct 1990	"
BUS 10 C	37.3	Oct 1990	"
Hisar			
Dryland Farm, HAU	36.8	Oct 1985 (?)	
Field 21, HAU Farm	43.6 - 104.7	July 1986 (?)	Data from non solarized plots of PA 86/6, C'Pea
Field 851, GLF	9.6 - 27.2	Oct 1986	Young Oats
Field 852, GLF	11.1 - 23.4	Oct 1986	Oats, Berseem & Chickpea, Chickpea part has maximum nitrogen
Field 887, GLF	7.4 - 11.4	Oct 1986	Oats and Brassica
Field 888, GLF	5.4 - 9.7	Oct 1986	Trifolium

(1)	(2)	(3)	(4)
Gwalior			
316	9.9 - 15.0	July 1986	Data taken from nonsolarized plots of PA 86/6, Chickpea and pigeonpea
324	15.5	July 1985	Top 20 cm profile
321	12.1 - 31.8	Oct 1986	
318	22.9	July 1988	
324	21.0 - 43.9	June 1988	Samples from six plots of different cropping systems.
308	26 - 29	Oct 1988	Available-N in lower depths was generally < 10 mg kg^{-1} soil.
Farmers' fields, Hisar			
	31.9	Nov 1990	Sampling in between plant rows in chickpea fields
	9.6	"	"
	16.8	"	"
	16.5	"	"
	14.8	"	"
	20.0	"	"
	18.7	"	"
	12.2	"	"
	22.7	"	"
	13.6	"	"
Farmers' fields, Gwalior			
	14.3	"	"
	21.2	"	"
	15.9	"	"
	25.8	"	"
	21.0	"	"
	16.2	"	"
	15.4	"	"
	20.7	"	"
	21.3	"	"

Note: 1) Soil moisture and nitrogen at sowing depth at early plant growth are most relevant factors to determine nodulation of chickpea grown on residual soil moisture. The available-N in the top 15 cm profile is thus a good indicator of N-effect on nodulation.

2) At least four spots were sampled from each field pooled and analysed. In some fields more than one such pooled samples were made, and therefore the N-concentration is shown by range.

GLF = Government livestock farm

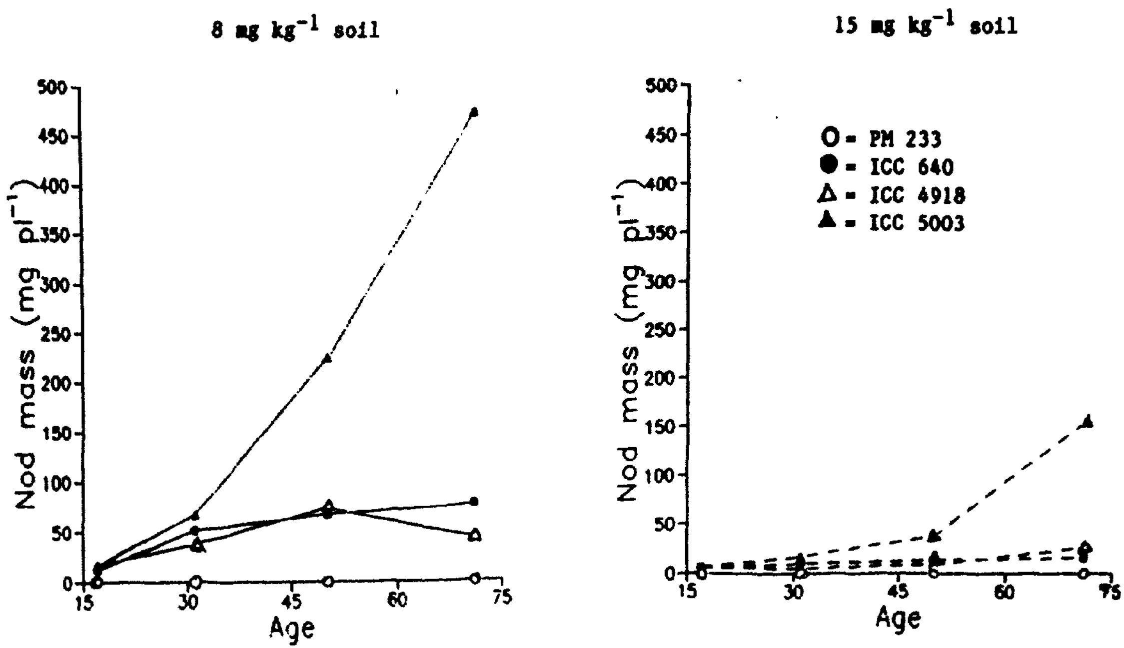

Fig.6.4.1Nodule mass (mg plant^{-1}) as affected by available-N concentration in Vertisol, ICRISA Center, postrainy season 1986/87.

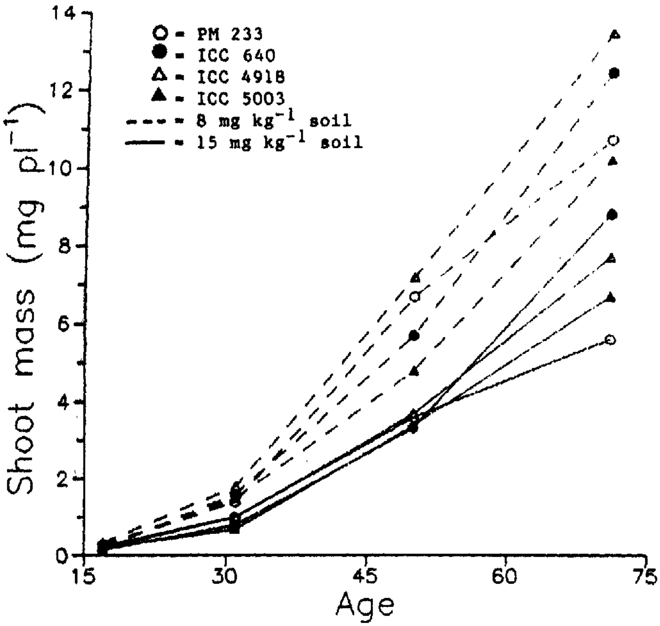

Fig.6.4.2 Shoot mass (g plant^{-1}) as affected by available-N concentration in Vertisol, ICRISAT Center, postrainy season 1986/87.

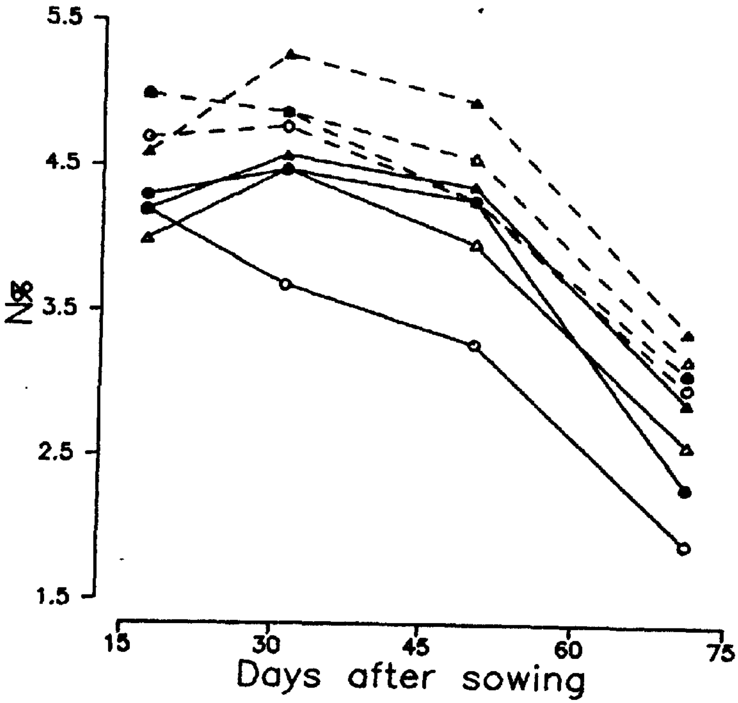

Fig. 6.4.3 Shoot N% of four chickpea lines PM 233 (○), ICC 640 (●), ICC 4918 (△) and ICC 5003 (▲) grown on Vertisol of 8 mg (——) and 37 mg (---) available-N in top 60 cm profile, postrainy season 1986/87, ICRISAT Center.

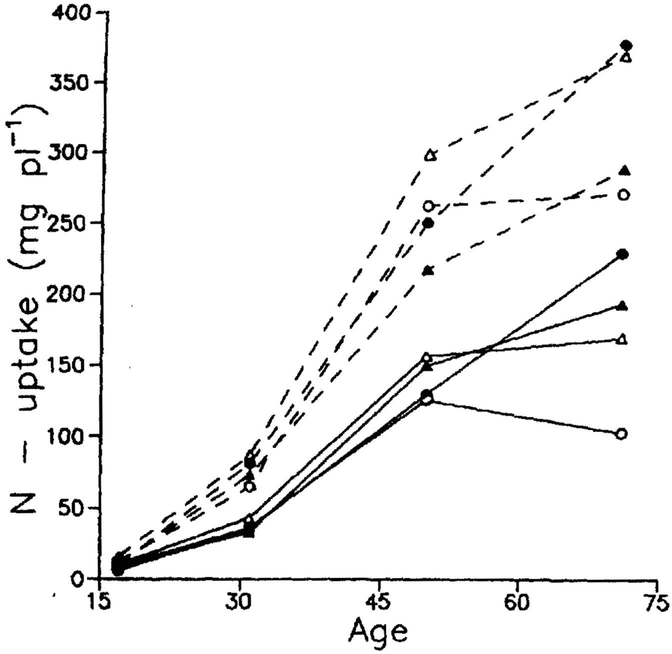

Fig.6.4.4 N-uptake (mg plant^{-1}) by four genotypes PM 233 (○), ICC 640 (●), ICC 4918 (△), and ICC 5003 (▲) as affected by available-N (- = 8 mg kg^{-1} soil, --- = 15 mg kg^{-1} soil) in a Vertisol, ICRISAT Center, postrainy season 1986/87.

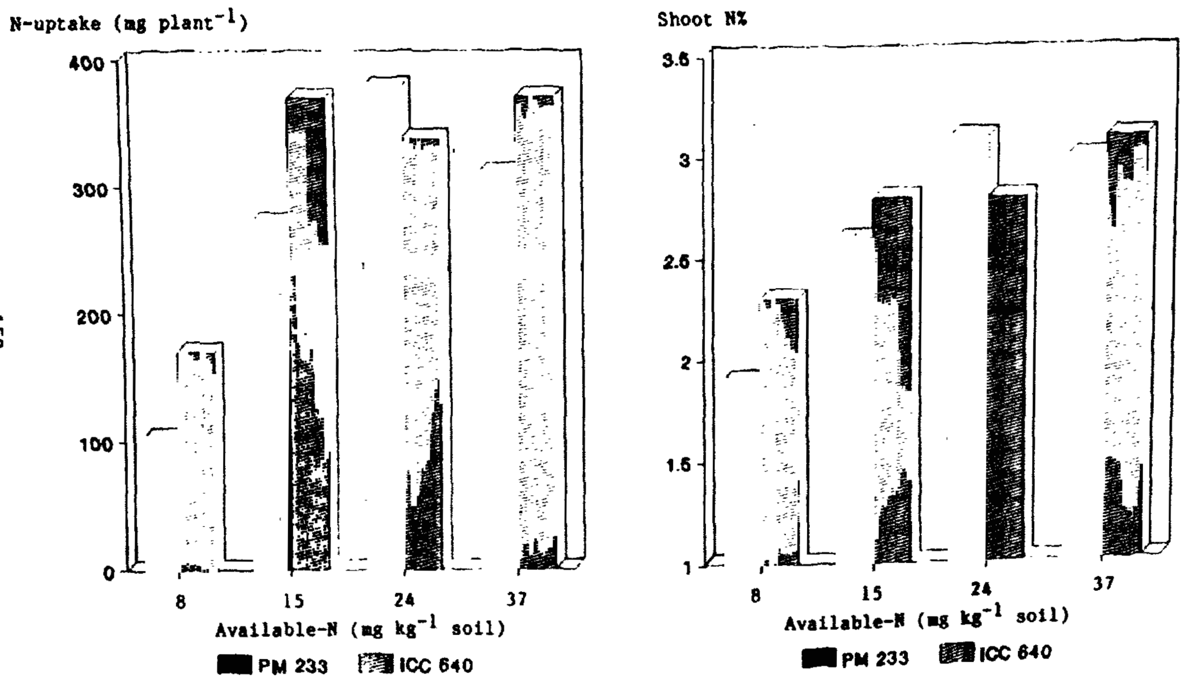

Fig.6.4.5 N-uptake (left, mg plant^{-1}) and shoot N% (right) of a nodulating chickpea line ICC 640 and its Nod$^-$ mutant PM 233 at 71 DAS, on a Vertisol with four different available-N levels, ICRISAT Center, postrainy season, 1986/87.

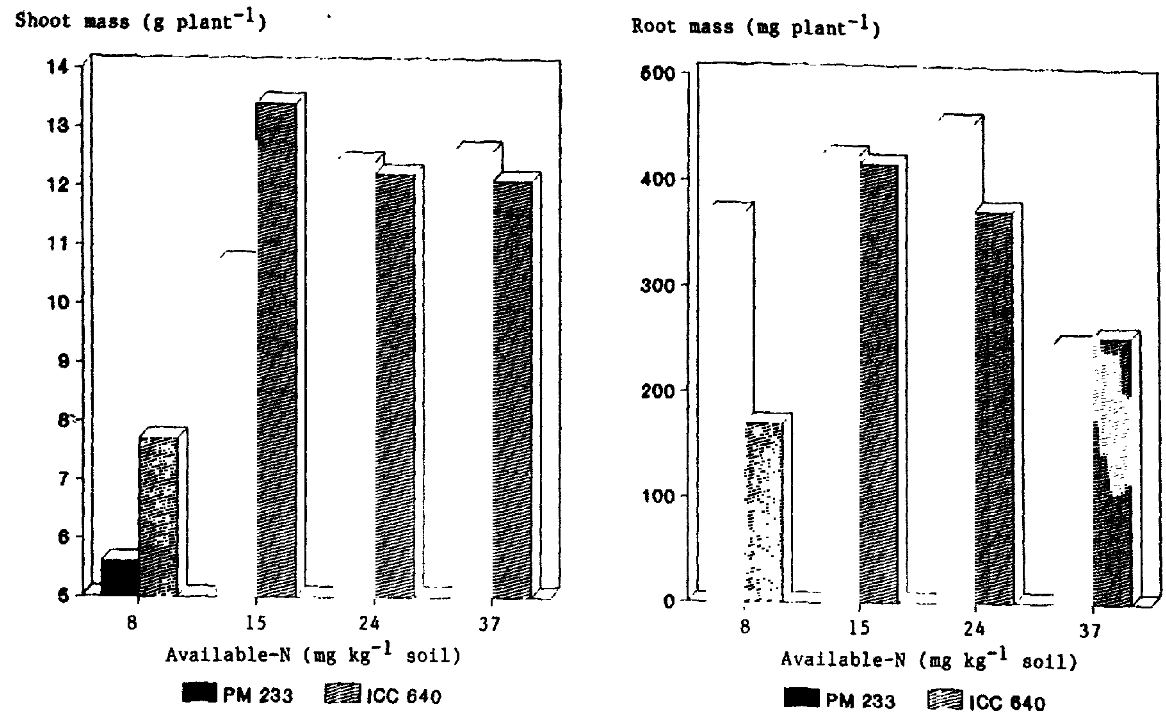

Fig.6.4.6Shoot mass (left, g plant^{-1}) and root mass (right, mg plant^{-1}) of ICC 640 and PM 233 at 71 DAS on a Vertisol with four different available-N levels, ICRISAT Center, postrainy, 1986/87.

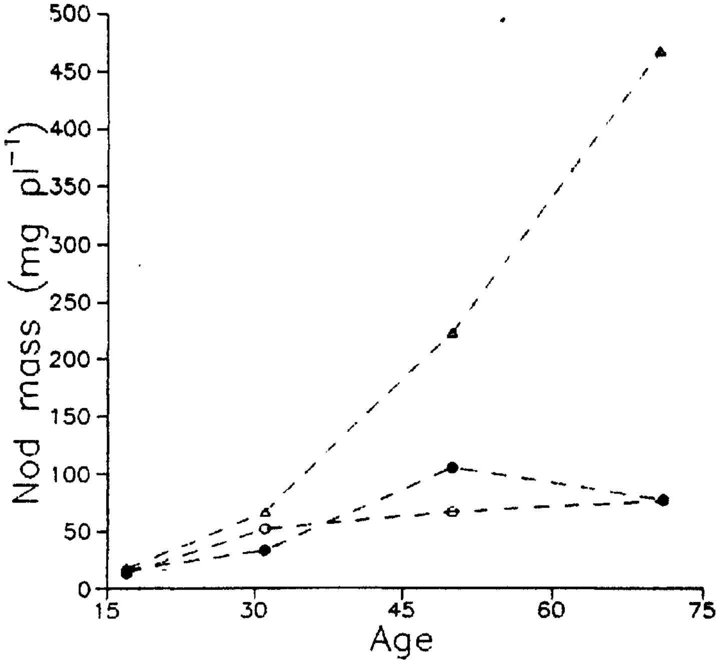

Fig.6.4.7 Nodule mass (mg plant^{-1}) of three chickpea lines ICC 4918 (○), ICC 5003 (△), and ICC 37 (●), through the season, on a Vertisol having 8 mg N kg^{-1} soil in the top 60 cm profile, ICRISAT Center, postrainy season 1986/87.

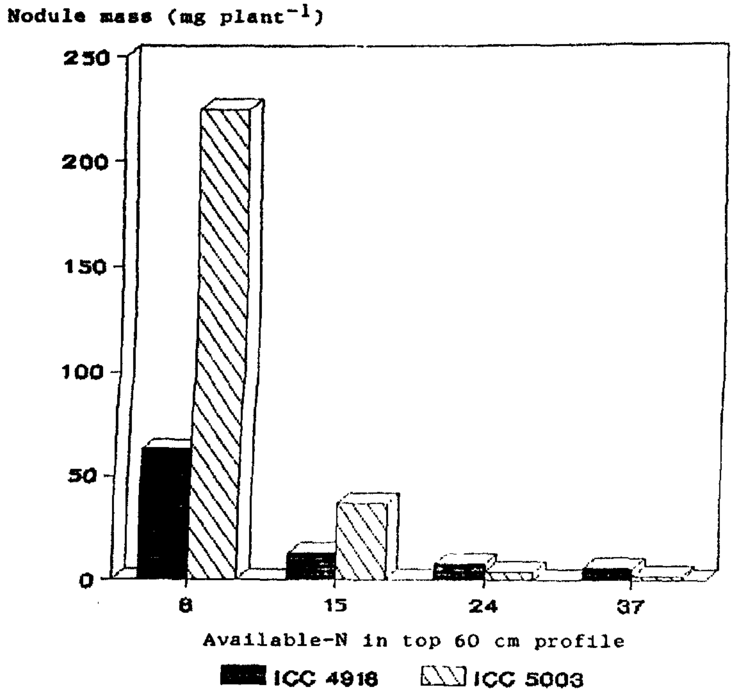

Fig.6.4.8Nodule mass (mg plant^{-1}) at 50 DAS of ICC 4918 and ICC 5003 as affected by available-N level in Vertisol, ICRISAT Center, postrainy season 1986/87.

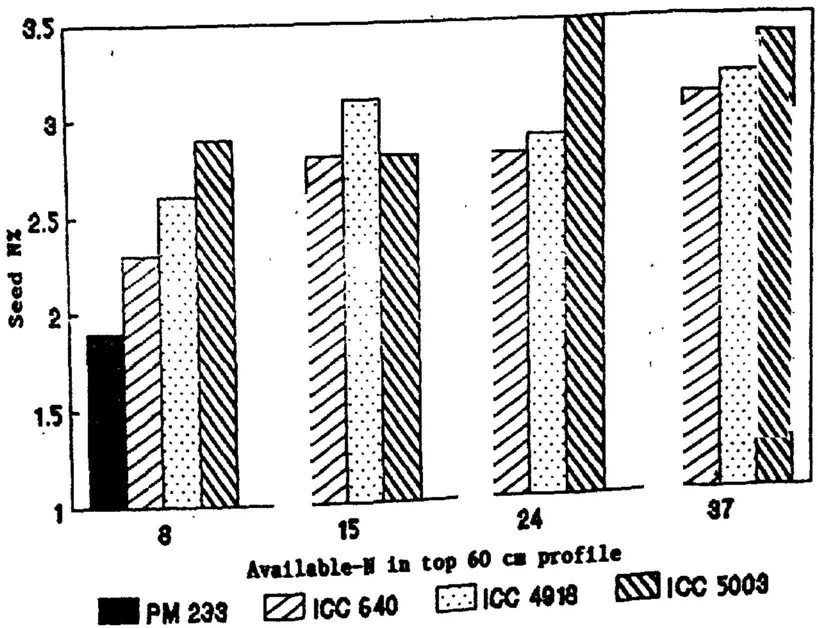

Fig.6.4.9 Seed N% of four chickpea lines as affected by four different levels of available-N in the top 60 cm profile of Vertisol, ICRISAT Center, postrainy season 1986/87.

6.5 PA 86/49 Natural occurrence of non-nodulating plants in chickpea and their frequency (OPR)

Report

We identified a non-nodulating (Nod^{-1}) plant of ICC 435 in 1985/86. This trial was designed to study the frequency of occurrence of such plants in four genotypes ICC 435, Annigeri (ICC 4918), G 130 (ICC 4998), and K 850 (ICC 5003) at 22 DAS and in ten genotypes Annigeri, G 130, K 850, L 550 (ICC 4973), Cyprus local (ICC 12328), Iranian local (ICC 12329), Jordanian local (ICC 12330), Rabat (ICC 4993), Syrian local, (ICC 12331), and Turkish local (ICC 12332) at 112 DAS when all genotypes were physiologically mature. At least 13000 plants to about 26000 plant per line were screened at 22 DAS and 500 to 2000 plants per line of the ten genotypes were screened at physiological maturity in field BP 2C. The frequency of occurrence of Nod^{-1} plants in the four genotypes screened at 22 DAS ranged from 120 per million in ICC 5003 to 473 per million in ICC 435. Of the 21 Nod^{-1} plants identified only seven plants survived the transplanting shock and adverse effects of fusarium wilt in the soil accidentally used for this trial. We had at least one Nod^{-1} plants each of ICC 475, ICC 4918, ICC 4993, and ICC 5003. These were confirmed and multiplied in further studies, and used in agronomic trials. Work done in this trial and portion of the further studies have been proposed as a journal article (JA 1067) that follows. It has been submitted to Crop Science.

Natural Occurrence of Nonnodulating Plants in Chickpea and their Salient Characters

O.P. Rupela

ABSTRACT

Large plant population of several genotypes grown on a field under conditions favouring good nodulation were uprooted to study natural occurrence of nonnodulation (Nod$^-$) trait and its frequency. Observations revealed presence of Nod$^-$ plants in five chickpea accessions ICC 435, -4918, -4948, -5003 and -4993. The frequency of their occurrence ranged from 120 to 472 plants per million in the first four accessions when examined at 22 days after sowing (DAS). Nod$^-$ plants could also be identified from two (ICC 4993 and -5003) of the ten accessions when limited population of each of these was examined at physiological maturity. Plants identified as Nod$^-$ under field conditions at 22 DAS were potted to produce seeds. Progenies of apparent Nod$^-$ plants were inoculated with Rhizobium strain IC 59 and grown in pots for 28 day for confirmation. Only one Nod$^-$ plant each of the four accessions ICC 435 -4918, -4993 and -5003 was used for reconfirmation studies under field conditions in the postrainy season 1987/88 and used for agronomic evaluation in subsequent studies. The Nod$^-$ lines of these accessions were indistinguishable for plant growth except for nodulation, and most yielded similar to their Nod$^+$ accessions, when supplied with moderate levels of N-fertilizer.

On a low-N field without fertilizer-N the Nod⁻ plants were light green, grew poorly, and had short internodal distance with small leaves and leaflets. 'Desi' types had reddish-brown pigment on margins of leaflets, rachis and sometimes on branches but lacked in those of 'Kabuli' types. All the Nod⁻ lines had apparently normal root hairs similar to parent type when examined under stereomicroscope.

Nonnodulating (Nod⁻) lines are valuable in assessing the amount of biological nitrogen fixed by the legume crops (5). The possibility of their use in developing host plants with restricted Rhizobium specificity, which would circumvent the problem of competition from native rhizobia, has also been indicated (4). The search for Nod⁻ chickpea plants began at ICRISAT Center (18° N latitude) in 1975 with initiation of research work on biological nitrogen fixation. Such plants occasionally observed during 1976-1980 in segregating F_2 and F_3 populations could not be saved due to lack of sufficient knowledge and expertise in salvaging the uprooted chickpea plants. These methods which became available in the early 1980's (2, 10), were used in recovering a Nod⁻ plant from a germplasm accession ICC 435, a land race from Bihar, India. Progenies of this plant were confirmed to be Nod⁻ and were similar to the parent type (11). This Nod⁻ line (named ICC 435M) of chickpea, unlike groundnut mutant with apparent light green foliage (6), did not show apparent N-deficiency symptoms when grown on traditional chickpea fields and thus suggested good soil-N scavenging ability of its root system. To study the frequency of occurrence of such plants, therefore, large number of field grown plants had to be uprooted and observed for nodulation. This paper describes the procedures followed to screen for Nod⁻ plants at early plant growth stage and at physiological maturity, frequency of their occurrence at early plant growth stages, and their salient characteristics.

MATERIALS AND METHODS

Large population of several chickpea accessions (Table 1) were grown on a Vertisol field with available-N concentration of about 19 mg kg^{-1} soil in the top 15 cm profile and chickpea Rhizobium count of 4.7×10^3 g^{-1} dry soil as measured by most probable number (MPN) plant infection technique (15). Screening for Nod⁻ plants was conducted on four germplasm accessions at early plant growth stage, 22 days after sowing (DAS), and on ten accessions at physiological maturity at 112 DAS (Table 1). Conditions of high native rhizobia, and good soil moisture, considered necessary for good nodulation of chickpea were ensured.

Plants were uprooted with a crowbar to a depth of about 20 cm to quantitatively recover roots and nodules. Apparently Nod⁻ plants identified at 22 DAS were counted, potted, inoculated with chickpea Rhizobium strain IC 59, and grown on to produce seeds, following the methods described by Rupela and Dart (10). Six hundred and forty to 2200 plants of each of the ten accessions were examined for nodulation at 112 DAS. Previous unpublished observations suggested that most chickpea nodules remain attached to roots when carefully dug at maturity. Irrigation, a few days before observation, facilitated uprooting of plants. Apparently Nod⁻ plants identified at 112 DAS were brought to the laboratory, the roots were soaked in water for about one hour, and observed again for nodules. Plants with tiny nodules were discarded and the seeds of the rest of the plants was preserved for future use.

Seeds could be produced from at least one Nod potted plants each from ICC 435, -4918, and -5003 identified at 22 DAS and sufficient seeds were available of Nod^- plants of ICC 4993 and -5003 identified at 112 DAS. Five to ten progeny seeds of each of these apparently Nod^- plants were sown in 10 cm diameter plastic pots filled with course river sand. Inoculation was done at sowing by applying 10 ml suspension of peat inoculant (*Rhizobium* strain IC 59) in water that had at least 10^8 rhizobia mL^{-1}. Watering was done with quarter strength nitrogen-free nutrient solution following Arnon (1), as and when required. Pots were placed in a glasshouse with max-min temperatures ranging 32-16 °C and relative humidity of about 70% during Feb and Mar 1987. Twenty-eight-day old plants were washed and examined for nodulation by spreading the root systems in enamel trays filled with water.

Progenies of the one confirmed Nod^- plant of each of the four accessions ICC-435, -4918, -4993 and -5003 were grown in the postrainy season of 1987/88 (November 1987 to April 1988) on an Inceptisol field at ICRISAT Subcenter, Gwalior, India (26°N latitude) for further confirmation against native rhizobia of a different environment. Wherever more than one Nod^- plants were available within an accession, these were stored for future studies. Plants were uprooted at 60 DAS for nodulation observations.

In the postrainy season 1988/89 (November 1988 to April 1989) the Nod^- lines of the four chickpea accessions described above, PM233, their Nod^+ parents, linseed (*Linum usitatissimum* L.) and barley (*Hordeum vulgare* L.) were grown on a low-N field at Gwalior each with six different N-fertilizer levels as main plot 0, 20, 50, 100, 150, and 200 kg N ha^{-1} for agronomic evaluations on plots of 4 m x 1.2 m in split plot design. The soil pH (1:2, soil:water), electrical conductivity, available-N, and Olsen-P in the top 30 cm soil profile at Gwalior, respectively ranged 8.1-8.3, 0.2-0.4 dS m^{-1}, 17-27 mg kg^{-1} soil, and 5-12 mg kg^{-1} soil. Chickpea *Rhizobium* count was 4.3×10^3 g^{-1} soil. Details of this study would be reported separately. However, nodulation observations on a sample of plants from 0.3 m^2 per plot at 58 DAS, apparent N-deficiency symptoms based on weekly visual records, and grain yield of 0N and 50 N treatments only for the chickpea accessions are reported here.

Root hair study was conducted on the Nod^- plants from the four lines reported here and on the mutant PM233 of Davis et al. (3). The relevant Nod^+ parent of these lines were included as checks. Fifty water-soaked seeds of each of these lines were germinated in 9 cm petri dishes lined with water soaked blotting paper. Plates were placed in a 8 L covered plastic container having a 2 cm water layer at the bottom. Temperature inside the container was 20-25°C. Radicles on 5-8 day old germinated seeds were observed for presence of root hairs under a stereo microscope at 20x to 60x.

RESULTS AND DISCUSSION

The frequency of occurrence of Nod^- character was calculated to range from 120 to 472 plants per million (Table 2). Fourteen of the 21 transplanted plants died due to fusarium wilt before producing seeds. However, all plants survived for at least three weeks and had formed new roots when examined; and one plant of ICC 4948 even produced nodules before dieing. Progenies of all the seven surviving Nod$^-$ plants from three accessions ICC 435, -4918, and -5003 did not form nodules when grown in pots inoculated with Rhizobium strain IC 59. Although the plant death due to fusarium wilt at transplanting made confirmation studies incomplete, the fact that fresh root formation was observed and even nodules on one of the 14 dieing plants were seen in addition to confirmation of Nod$^-$ trait of all the seven survivors lend the data on frequency of occurrence a credibility. Plants from seeds of Nod$^+$ parents of these accessions nodulated normally under the same conditions. Chances of correct identification of Nod$^-$ plants from field grown population at early plant growth stages was thus very good, but was associated with large efforts of salvaging these plants and risk of plant death due to adverse factors such as diseases. It also required glasshouse facilities. Only two (one each of ICC 4993 and ICC 5003) of the five apparent Nod$^-$ plants selected at physiological maturity were actually Nod$^-$. The latter method to identify natural Nod$^-$ plants seemed more convenient and may be applied to legumes where most nodules remain attached to roots even at physiological maturity, for example in groundnut and chickpea.

Progenies of the confirmed Nod$^-$ plants in subsequent studies on an Inceptisol at ICRISAT Subcenter, Gwalior in the postrainy season of 1987/88 did not produce any nodules with native rhizobia at these locations. This further confirmed that the identified Nod$^-$ plants were not only resistant to strain IC 59 (used in confirmation studies in pots) but also to the mixture of Rhizobium strains that probably occurred in field soils and were thus stable. These plants grew similar to their Nod$^+$ accessions in this field upto 65 days when they were uprooted for nodulation observations and indicated their ability to grow good on the native soil fertility.

On a low-N field without fertilizer in the postrainy season 1988/89 the Nod$^-$ lines at 60 DAS grew poorly, had small leaves and leaflets, short internodal distance, and light green foliage compared to respective Nod$^+$ accession. 'Desi' lines had red-brown margins on leaflets, rachis, and sometimes on stems and were most conspicuous in ICC 4918M and PM233. These symptoms matched well with the N-deficiency symptoms described for a chickpea line Tyson by Smith and Pieters (14). It seems that 'Desi' chickpea lines display reddish-brown pigment under several stresses such as salinity, and stunt disease (9). It should, however, be possible to separate N-deficiency from other stresses due to symptoms other than the pigment. 'Kabuli' line ICC 4993 did not show the characteristic reddish-brown pigment of the kind seen on the 'Desi' types. In N-fertilized plots these symptoms were absent. With moderate application of urea (50 kg N ha^{-1}) most lines yielded similar to their respective Nod$^+$ accessions except PM 233 and ICC 4918 M (Table 3). These two lines seemed to require more N to produce at par their Nod$^+$ accessions. All the Nod$^-$ lines did not nodulate. Occasional Nod$^+$ plant observed in ICC 5003M was considered contaminant and discarded.

Very dense root hairs were generally observed 5-7 mm above root tips. All the radicles of Nod$^-$ plants including that of the irradiation mutant PM233 (3), and their Nod$^+$ parents had apparently normal root hairs. This suggested that, unlike groundnut (7), the Nod$^-$ trait of chickpea is due to factor(s) other than absence of root hairs. Presence of root hairs perhaps allowed the Nod$^-$ plants to scavenge the soil-N pool efficiently and made their visual identification difficult in the traditional chickpea fields. Leaves of Nod$^-$ groundnut that lacked root hairs, were generally pale green and the plants did not grow at par with nodulated groundnut even when fertilized with 400 kg N ha^{-1} (8). Chickpea Nod$^-$ lines thus appeared suitable reference plants for biological nitrogen fixation studies.

Contrary to Davis et al. (3) who screened about 10000 M_2 seedlings to identify one stable Nod$^-$ chickpea line, it was felt that searching for natural Nod$^-$ plants would be much faster and easier than developing induced Nod$^-$ mutants. After screening a similar population size we could identify Nod$^-$ plants without the efforts of mutagenesis. Also, in natural Nod$^-$ plants the chances of occurrence of undesirable changes, possible with mutagenized plants, on the genetic composition of identified plants were less and thus further studies to establish stable and desirable Nod$^-$ plants would not be required.

It is highly likely that all the Nod$^-$ plants within a genotype are genetically same and are progenies of a natural mutation that occurred in the past. This needs to be examined. However, the Nod$^-$ plants across different accessions may be due to a mutation at different loci as established in the case of ICC 435M and PM233 (13). Seeds of Nod$^-$ lines have already been given to interested researchers and would soon be a part of gene bank at ICRISAT Center for general distribution.

At least three Nod$^-$ plants were identified from each of the four accessions where population of 14000 or more was screened. This suggests their wider occurrence than may be generally believed. The wide occurrence of Nod$^-$ trait may be due to likely preference of chickpea plants for soil-N over symbiotic-N. Poor nodulation due to low soil moisture at sowing and high soil-N etc may encourage their occurrence. A survey of farmers fields in a chickpea growing region indicated great scope of poor nodulation due to factors other than the absence of native rhizobia (12). The unfavourable nodulation conditions perhaps forced plants to shed off non-functional appendages and the Nod$^-$ types perhaps evolved.

In our screening procedure we looked for Nod$^-$ plants only. It seems that some accessions may have natural variants of traits that may not be very apparent unless screened under right conditions. For example, some researchers have noticed occasional fusarium wilt resistant plants within a susceptible line in a disease screening nursery and found that the progeny of such plants was similar to parent type and was wilt resistant (Personal communication, Dr M.P. Haware, December, 1990). Screening for naturally occuring desirable traits thus offers a good opportunity of identifying genetic variability.

CONCLUSIONS

Natural occurrence of Nod$^-$ plants within an accession seems wider than may be generally believed. It is highly likely that the Nod$^-$ plants within a genotype are progenies of a mutation that may have occurred long ago. However, the Nod$^-$ plants across accessions may be nonallelic for this trait. The fact that Nod$^-$ and Nod$^+$ types of an accession could not be distinguished for plant growth under N-sufficient conditions suggested that they are efficient in soil-N uptake unlike the Nod$^-$ line of groundnut (8). On low-N fields without fertilizer-N the Nod$^-$ plants showed N-deficiency symptoms that matched well with those described by Smith and Pieters (14) but the 'Kabuli' line did not have the characteristic reddish-brown pigment of 'Desi' types. This suggested a scope of identifying Nod^- plants on low-N fields without uprooting at early plant growth stages.

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Table 1. Description of chickpea accessions used in the search for Nod$^-$ plants at early plant growth stage and at physiological maturity.

Accession	Synonyms	Age at screening (DAS)	Seed type	Origin	Maturity	Remarks
ICC 435	P 319-1	22		India		Land race
ICC 4918	Annigeri	22,112		India		Selection from a land race
ICC 4948	G 130	22,112		India		Land race
ICC 4973	L 550	112		India		Bred variety
ICC 4993	Rabat	112		Morocco		Land race
ICC 5003	K 850, 850-3/27	22,112		India		Bred variety
ICC 12328	Cyprus local	112		Cyprus		Land race
ICC 12329	Iranian local	112		Iran		Land race
ICC 12330	Jordanian local	112		Jordan		Land race
ICC 12331	Syrian local	112		Syria		Land race
ICC 12332	Turkish local	112		Turkey		Land race

= DESI - light to dark brown color and angular head seeds,
= KABULI - mediterranean type, beige or ivory color, owl's head shape seeds,
= long duration, = medium duraion, = short duration

Table 2. Frequency of naturally occurring Nod$^-$ plants in four chickpea accessions measured at early plant growth stage.

	Field studies		Frequency of Nod$^-$ trait (no. per million)
Accession	No. of plants observed in field	Apparent Nod$^-$ plants	
ICC 435	14812	7	472
ICC 4918	26190	4	153
ICC 4948	36260	7 [1]	165
ICC 5003	25056	3	120

1 One of the seven plants formed nodules after transplanting.

Table 3. Salient characters of Nod^- lines compared with respective Nod^+ accession at 0 kg (0N) and 50 kg N ha^{-1} (50 N), Gwalior, postrainy season 1988/89.

Chickpea line[1]	Nodule mass ($g\ m^{-2}$) at 58 DAS		Apparent N-deficiency symptoms[2]		Grain yield ($t\ ha^{-1}$)	
	0N	50 N	0N	50 N	0N	50 N
ICC 435	10.8	9.4	-	-	3.57	2.58
ICC 435 M	0	0	+	-	2.24	3.02
ICC 4918	7.0	4.6	-	-	2.91	3.25
ICC 4918 M	0	0	+	-	1.56	2.36
ICC 4993	5.4	4.0	-	-	2.55	2.40
ICC 4993 M	0	0	+	-	2.06	2.33
ICC 5003	12.3	6.4	-	-	3.70	2.69
ICC 5003 M	0	0	+	-	2.69	3.32
ICC 640	7.3	3.5	-	-	2.98	3.53
PM 233	0	0	+	-	1.87	2.36
LSD (0.05)					0.468	

1. Accession no. suffixed with M are the Nod^- lines of the respective accession. PM 233 is Nod^- mutant of ICC 640(3)

2. Observation at 60 DAS, -, + = Absence and presence of N-deficiency symptoms.

7. CP-113(85)IC Identification of situations where chickpea and pigeonpea respond to Rhizobium inoculation

7.1 Objectives

a) To determine and document the optimum methodology for "need to inoculate" trials specifically for chickpea and pigeonpea.

b) To evaluate whether estimates of soil rhizobial numbers alone (e.g. MPN counts), or in combination with various soil properties and previous cropping history, can reasonably predict inoculation response.

c) To understand short-term and long-term survival, location in the soil profile and competitive ability of native and inoculated rhizobial strains.

7.2 PA 86/12 The interaction of solarization and rhizobial inoculation in chickpea (OPR, CJ, YSC, KRK)

Report

In a previous experiment solarization reduced the native chickpea rhizobia in the top 15 cm soil profile by at least 100 fold when measured soon after solarization in June 1985 (see PA 85/16 in Chickpea Agronomy Progress Report No.1 pp 28-41). Before sowing chickpea in October 1985 the Rhizobium population increased in some solarized plots. However, reduced nodulation was observed in solarized plots. Between June, when solarization treatment was completed, and the following October the land remained fallow. In the two years the experiment was conducted, chickpea was sown on residual soil moisture without any supplemental irrigation and tillage before sowing. This perhaps resulted in poor plant growth. However, without inoculation, the nodule number and mass was substantially reduced due to solarization. In inoculated sub-plots, there was no improvement in nodulation over the noninoculated treatment, perhaps due to the poor soil moisture conditions.

In this trial we further examined the extent to which rhizobial numbers are affected due to solarization, whether this has any adverse effects on chickpea nodulation and, if so, can this effect be minimized by rhizobial inoculation.

It is the common experience of many BNF workers that inoculant strains rarely form more than 50% of the total nodules on a plant when the native population is high (10^3 and more rhizobia g^{-1} dry soil). In our previous trials on chickpea grown on residual soil moisture about 10% of the nodules were generally formed by the inoculant strains. Solarization, which killed native rhizobia, as suggested by our earlier observations, offered a possibility to displace native rhizobia and hence this was an additional objective of the trial. The work done under this experiment has been published in Biology and Fertility of Soils 10: 207-212 that follows.

Biol Fertil Soils (1990) 10:207-212

Biology and Fertility of Soils

Displacement of native rhizobia nodulating chickpea (*Cicer arietinum* L.) by an inoculant strain through soil solarization *

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Summary. Soil solarization greatly reduced the native chickpea *Rhizobium* population. With inoculation, it was possible to increase the population of the *Rhizobium* in solarized plots. In the 1st year, 47% nodulation was obtained with chickpea inoculant strain IC 59 when introduced with a cereal crop 2 weeks after the soil solarization and having a native *Rhizobium* count of $<10\ g^{-1}$ soil, and only 13% when introduced 16 weeks after solarization at the time the chickpeas were sown, with 2.0×10^2 native rhizobia g^{-1} soil. In the non-solarized plots inoculated with 5.6×10^3 native rhizobia g^{-1} soil, only 6% nodulation was obtained with the inoculant. In the succeeding year, non-inoculated chickpea was grown on the same plots without any solarization or *Rhizobium* inoculation. The treatment that showed good establishment of the inoculant strain in year 1 formed 68% inoculant nodules. Other treatments indicated a further reduction in inoculant success, from 1%-13% to 1%-9%. Soil solarization thus allowed an inoculant strain to successfully displace the high native population in the field and can serve as a research tool to compare strains in the field, irrespective of competitive ability. In year 1, *Rhizobium* inoculation of chickpea gave increased nodulation and increased plant growth 20 and 51 days after sowing, and increased dry matter, grain yield, and grain protein yield at maturity. These beneficial effects of inoculation on plant growth and yield were not measured in the 2nd year.

Key words: Soil solarization – Displacing native rhizobia – Chickpea – *Cicer arietinum* – Survival of inoculant strain – *Rhizobium* spp.

It is generally difficult to displace indigenous rhizobia with inoculant strains, and most nodules on the host legume are formed by native rhizobia (Bohlool and Schmidt 1973; Kvien et al. 1981; Moawad et al. 1984). However, this is only likely to occur where the native *Rhizobium* population is low or absent (Materon and Hagedorn 1982; May and Bohlool 1983). The degree of establishment and the persistence of inoculant rhizobia generally decreases with increasing population density of the native rhizobia (Roughley et al. 1976; ICRISAT 1981). However, some inoculant strains have succeeded in forming the greatest number of nodules even in the presence of active indigenous competing rhizobia, e.g., Viking 1 on French beans (Robert and Schmidt 1983), G 1067 on *Trifolium* (McLoughlin et al. 1984), and NC 92 on groundnuts (Nambiar et al. 1984). The reason(s) for these successes is not well understood. The often poor ability of inoculant strains to compete with the native populations and the importance of identifying competitive strains have recently been reviewed by Schmidt (1988).

High temperatures may adversely affect the survival of rhizobia in soil. When exposed to a continuous incubation temperature of 46°C all 10 *Rhizobium* strains on different legumes, including one strain (TAL 620, ICRISAT 3889) on chickpeas, died within a week (Somasegaran et al. 1984). In the field, even higher temperatures occur (Somasegaran et al. 1984) but with diurnal changes/fluctuations. Soil solarization, i.e., heating the topsoil by covering it with transparent polythene sheeting during the hot summer period, increased the duration of high soil temperatures and heated the soil to a greater depth than the control soil (Chauhan et al. 1988). Further, solarization of well watered soil markedly reduced chickpea rhizobial populations. Since the inoculant strains became well established when native rhizobial populations were low (Materon and Hagedorn 1982), soil solarization thus made it possible to establish inoculant strains in fields with high native rhizobial populations. The objective of the present study was to test this use of solarization.

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Materials and methods

Soil and solarization

A Vertisol (Typic Pellustert) field, previously depleted of soil N by growing cereal cover crops, was selected at the ICRISAT Center. The soil had a native population of 1.9×10^4 chickpea rhizobia g^{-1}. Before solarization, the soil pH (1:2, soil: water) was 8.1–8.2, electrical conductivity was 0.21–0.33 dS m^{-1}, NO_3^--N was 2.9–4.1 ppm, NH_4^+-N was 6.6–9.0 ppm, Olsen P was 5.3–7.0 ppm, and organic C was 1.0%–1.6% in the top 15 cm of the profile.

The field was prepared in 60-cm ridges and furrows, and was irrigated. The plots to be treated by solarization were covered with clear polythene sheeting of 400 gauge thickness 4 days after the irrigation and left for 50 days, from 22 April to 11 June 1986 (Chauhan et al. 1988). In the following year the land was left fallow, without solarization during the summer.

Soil temperature

Soil thermometers with metal jackets were used to measure the temperatures at depths of 5, 10, and 20 cm in the solarized and non-solarized plots. The thermometers pierced the polythene sheeting to the desired depth, both on top of the ridges and in the furrows. The joints were sealed with silicone rubber sealant. Daily readings were taken at 0830 and 1500 h. On 4 clear days, temperatures were recorded at hourly intervals to measure the diurnal fluctuations in the soil and the atmospheric air temperature.

Rhizobium strain

Rhizobia that nodulate chickpea are very specific and do not show a cross-inoculation affinity with any of the members of known cross-inoculation groups (references in Rupela and Saxena 1987). According to the 9th edition of Bergey's Manual of Systematic Bacteriology these have been called *Bradyrhizobium* sp. (Cicer), but in the present paper the species is termed chickpea *Rhizobium*. Strain IC 59 was obtained from a *Rhizobium* culture collection maintained at the ICRISAT Center. Earlier unpublished studies showed that this strain was efficient in pot culture at the ICRISAT Center and in multilocational field studies in India conducted by the All India Coordinated Pulse Improvement Project (AICPIP) under the auspices of the Indian Council of Agricultural Research (ICAR).

Chickpea Rhizobium count

Soil samples (pool of four cores plot^{-1} from the top 15 cm of the profile) were collected after solarization and before the chickpeas were sown about 4 months after the solarization, using a 40-mm diameter soil corer. The population of chickpea rhizobia (most probable number) in these samples was determined by using a plant infection technique, as described by Toomsan et al. (1984).

Experimental design

The six treatments in the study comprised applications of *Rhizobium* at the time of sowing both sorghum and chickpeas, application of *Rhizobium* at the sowing of chickpeas only, and a non-inoculated control, each with and without solarization. These treatments were applied in field plots of 6×6 m in a random block design with six replications. The plots were separated by 2-m buffer zones.

Cover crop and application of Rhizobium strain to the soil

Solarization is known to increase soil nitrate levels by increased mineralization (Chauhan et al. 1988). To deplete this nitrate in the solarized plots and minimize its effects on chickpea growth and nodulation, a cover crop of sorghum was grown after the solarization and before the chickpeas were sown. As noted above, the inoculant strain was introduced along with sorghum in selected treatments, 2 weeks after soil solarization (on 28 June 1986), along the furrows that were opened on top of the ridges; a liquid suspension of peat-based inoculant strain IC 59 in water was used (1 g carrier with 1.4×10^9 rhizobia liter^{-1} of water). The suspension was applied evenly at the rate of 165 ml m^{-1} row. Seeds of the sorghum hybrid CSH 6 were then placed in the opened furrows and covered with soil. This cover crop was rainfed, except for one sprinkler irrigation provided soon after sowing. About 430 mm rain fell during the crop growth period. Throughout the season, no rainwater was allowed to flow across the plots. During routine hand-weeding and interculture operations care was taken to minimize any mixing of soil and of rhizobia between plots. The sorghum was harvested 110 days after sowing.

Chickpea 1986–1987 (year 1)

After the sorghum was harvested on 6 October 1986, the land was plowed and remade into 60-cm ridges. It was hoped that the buffer zones between the plots would minimize the transfer of soil from one treatment plot to the next by farm machinery. The chickpea genotype Annigeri was sown in two rows per ridge at 30×10 cm spacing on 25 October 1986. The inoculant strain was applied at the time the chickpeas were sown, as described for sorghum. Thus half the total of 24 inoculated plots were treated with inoculant *Rhizobium* sp. for the first time. A post-sowing irrigation was provided, through a sprinkler system equivalent to a total of 42 mm rain, between 7 and 15 days after sowing. No further irrigation was provided, though moisture stress, as evidenced by dark green foliage, was observed about 60 days after sowing. Routine plant protection and weeding operations were performed. The chickpeas were harvested on 16 February 1987.

Chickpea 1987–1988 (year 2)

The land remained fallow without solarization after the 1st year's harvest of the chickpea crop on 16 February 1987. A normal weed flora was present when the land was prepared for sowing the non-inculated chickpeas on 25 November 1987. The seeds were sown on ridges 75 cm apart at 37.5×10 cm spacing. The crop was harvested 117 days after sowing. During the crop growth period, about 245 mm rain fell.

Nodulation, N_2 fixation, and plant growth of chickpeas

Roots, nodules, and tops were sampled from all the replicate plots for all treatments 20 and 51 days after sowing in year 1 and 47 days after sowing in year 2. Twelve plants per plot were carefully excavated up to 20 cm in depth for this purpose. Following an acetylene reduction test and recording of the fresh mass, all the nodules were preserved at −20°C in 20% glycerol solution for serotyping. The plants sampled during year 2 were not subjected to the acetylene reduction assay. All plant samples were dried at about 70°C, weighed, and ground in a Wiley mill mounted with a 0.2-mm sieve for determination of the N content.

All freshly excavated roots and nodules from each plot were subjected to an acetylene reduction assay in 6-liter airtight plastic containers, as described by Dart et al. (1972). Gas samples were taken after 30 min and the ethylene content was determined using a Pye Unicam gas chromatograph with a flame ionization detector.

Serotyping of nodules

Preparation of whole-cell antigen and antiserum were carried out as described by Vincent (1970), and the agglutination titer of the serum prepared was ≤1/100. All the stored nodules in both years were washed with sterile water and subsampled. For the serotyping, the alkaline phosphatase-based double-antibody sandwich form of direct enzyme-linked immunosorbent assay (ELISA) was used (Kishinevsky and Bar-Joseph 1978).

Results and discussion

Soil temperature

A temperature of 50 °C or more was recorded on 45 of the 50 days of solarization and the temperature at the top of the ridges was generally 0.5°–1 °C higher than that in the furrows. The soil temperature ranged from 42° to 55 °C in the top 20 cm of the profile between 1100 and 1800 h on 6 June 1986 (Fig. 1), with the highest temperature at a depth of 5 cm and the lowest at 20 cm. Over the rest of the day the highest temperature occurred at a depth of 20 cm and the lowest at 5 cm, with a range of 33°–46 °C. The temperature at the 10-cm depth was generally between those of the 5-cm and the 20-cm depths; in the top 10 cm of the profile the temperature reached ≥50 °C for about 5 h a day in the solarized plots. In the non-solarized plots the soil temperature in the top 10 cm of the profile ranged from 42° to 48 °C even in the hottest period of the day (1100–1800 h). Soil temperatures above 45 °C may kill rhizobia (Somasegaran et al. 1984), and the soil temperatures in solarized plots may decrease the survival of rhizobia well below that in the non-solarized plots.

Solarization and Rhizobium population

Solarization substantially decreased the native *Rhizobium* population in the top 15 cm of the profile when measured soon after solarization, from 2.2×10^3 to <10 rhizobia g^{-1} soil in the solarized plots. The extent of the decrease was similar to that reported by Chauhan et al. (1988) for a different Vertisol field at the ICRISAT Center. At the time the chickpeas were sown, the population of native rhizobia increased in all plots. From <10 rhizobia g^{-1} of soil in the solarized plots, the number swelled to 200 cells (2.31 $\log_{10}$) in the non-inoculated plots and 5.6×10^3 (3.75 $\log_{10}$) rhizobia in the inoculated plots. The population in the plots inoculated with sorghum when chickpeas were sown was, respectively, twofold and fivefold higher in the solarized and non-solarized inoculated plots compared with the population measured before the solarization.

Cover crop of sorghum

The significant soil chemical change brought about by solarization was a substantial increase in soil nitrate. The level was at least double in the solarized compared with the non-solarized treatments (Chauhan et al. 1988). A sorghum cover crop was therefore grown soon after solarization to deplete the excess NO_3-N. The planting of sorghum also filled the large gap between solarization during the summer (April to June), and the normal time for sowing chickpeas (October/November).

In the solarized plots the sorghum produced about twice the above-ground biomass and threefold more seed yield than in the non-solarized plots, from which 2800 kg biomass ha^{-1} and 360 kg grain ha^{-1} were obtained. Data on the growth of sorghum as influenced by solarization are being reported separately (O. P. Rupela, N. Seetharama, and M. R. Sudarashana).

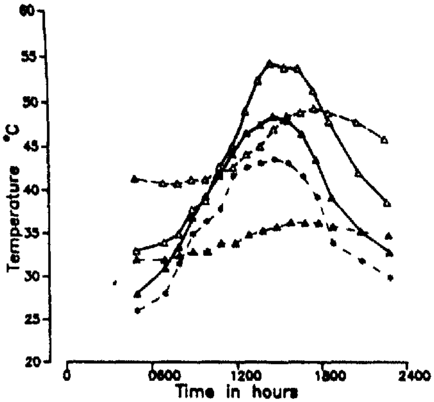

Fig. 1. Diurnal changes in soil temperatures in solarized (Δ) and non-solarized (▲) plots at soil depths of 5 cm (——) and 20 cm (– – –), and atmospheric air temperature (• – •) on 6 June 1989, 5 days before the end of the solarization period

Nodulation, N_2 fixation, and plant growth of chickpeas

The solarized non-inoculated plots had the fewest nodules and the smallest nodule mass both 20 and 51 days after sowing (Tables 1 and 2). Twenty days after sowing the solarized plots with dual inoculation, both sorghum and chickpea, had statistically more nodules per plant than the solarized non-inoculated control. The nodule count 51 days after sowing was similar with and without chickpea inoculation. The treatment with a dual application of *Rhizobium* sp., however, showed the maximum numbers of nodules (Table 1). With dual inoculation the nodule mass was also at a maximum. These differences did not appear among the non-solarized treatments (Table 2).

Acetylene reduction activity plant^{-1} h^{-1} was generally similar both in the plots with and without *Rhizobium* inoculation (Table 2). However, in the solarized inoculated plots the N concentration in shoots and the N uptake per plant were, respectively, 10% and 40% greater than in the solarized non-inoculated plots. The N uptake in the non-solarized inoculated plots was 8% greater than that in the non-solarized non-inoculated plots (Table 2). The application of the *Rhizobium* inoculant increased plant growth by 4%–9% by 20 days after sowing and 9%–20% by 51 days after sowing over the non-inoculated treatments (Table 2).

The chickpea growth in year 2 was superior to that in year 1 due to the apparently better soil moisture conditions. About 240 mm rain fell 2–5 weeks after sowing. In year 1, only 42 mm rain fell during the crop growth period. Unlike year 1, the *Rhizobium*-inoculated plots were only marginally superior to the non-inoculated plots for nodulation and plant growth 47 days after sowing, and for grain protein and protein yield at the final harvest (Table 3).

Table 1. *Rhizobium* population (no. g^{-1} soil), nodule numbers ($plant^{-1}$), and the percentage nodulation obtained from the inoculant strain with and without inoculation and soil solarization

Treatment[a]	*Rhizobium* population at chickpea sowing time, year 1 (log_{10})	Nodules (no. $plant^{-1}$)		Nodulation by inoculant strain[b] (%)	
		Year 1, 51 DAS	Year 2, 47 DAS	Year 1, 51 DAS	Year 2, 47 DAS
Solarized					
SCP	3.75	27	39	47.0 (43.0)	68.3 (56.2)
CP	2.10	24	36	13.2 (20.7)	9.3 (16.0)
C	2.31	20	35	1.0 (3.2)	1.0 (3.2)
Non-solarized					
SCP	4.04	32	41	6.2 (14.2)	2.0 (6.6)
CP	4.09	31	36	6.6 (11.9)	1.9 (7.7)
C	3.75	31	35	0 (0)	0.6 (3.2)
± SE	0.212	2.0	1.4	(3.70)	(4.77)
CV (%)	16	18	9	(59)	(75)

[a] SCP, inoculant applied when both sorghum and chickpeas were sown; CP, inoculant applied when chickpeas were sown; C, non-inoculated control; CV, coefficient of variation

DAS, days after sowing

[b] Data analysed after angular transformation; transformed values in parentheses

Table 2. Nodulation, N_2 fixation, shoot mass, and shoot N content of chickpeas with and without *Rhizobium* inoculation and soil solarization in year 1

Treatment	Nodules, 20 DAS (no. $plant^{-1}$)	Nodule fresh mass (mg $plant^{-1}$)		Acetylene reduction activity (μM C_2H_4 $plant^{-1}$ h^{-1})		Dry shoot mass (mg $plant^{-1}$)		Shoot N content, 51 DAS	
		20 DAS	51 DAS	20 DAS	51 DAS	20 DAS	51 DAS	%	mg $plant^{-1}$
Solarized									
SCP	27	224	653	1.8	1.8	189	2490	3.9	97
CP	15	197	616	1.6	2.0	181	2140	3.8	82
C	14	193	514	1.7	1.8	183	1790	3.5	64
Non-solarized									
SCP	32	228	649	1.7	2.0	161	2220	3.8	85
CP	31	231	667	1.7	2.1	175	2520	4.0	101
C	28	204	626	1.6	2.6	154	2170	3.9	86
± SE	1.6	16	61.9	0.18	0.37	7.4	143	0.10	6.4
CV (%)	16	19	24	27	44	10	16	6	18

See footnote a to Table 1

Dry matter, grain yield, per cent grain protein, and protein yield

In year 1, the nodulation and the early plant growth differences between treatments in the solarized plots were reflected in the final yield. An increased yield due to the *Rhizobium* inoculation was even observed in some non-solarized plots, but the difference was statistically significant only for grain yield; in the solarized plots significantly improved yields over the respective non-inoculated plots were recorded both for dry matter and grain yield. The mean increase ranged from 15% to 19% in the solarized inoculated treatments and from 13% to 14% in the non-solarized inoculated treatments (Table 3). The percentage of grain protein also improved with inoculation, by 4%–5%, and resulted in significantly more grain protein yield over the non-inoculated plots, both with and without solarization. Although inoculation treatment improved the yield components, the plants in the solarized plots yielded less as a whole. This may have been due to excessive depletion of nutrients in the solarized plots where sorghum was grown in the previous season and the solarized plots produced twofold more biomass. However, the amounts of soil N and soil P were similar in both the solarized and non-solarized plots at the time the chickpeas were sown. In year 2, the treatment differences were not apparent for any yield parameters studied (Table 3).

Tracing the inoculant strain

Although the antiserum had a low agglutination titer (≤ 1/100), it was successfully used in the ELISA. The serum showed no positive reaction with any of the nodules formed by native rhizobia in the same field, on plants away from the experimental area, nor did it show any cross-reaction with several other *Rhizobium* strains in our collection. In year 1, most nodules were formed by the inoculant strain (47%) when it was introduced, soon after solarization, with the sowing of the sorghum, and subsequently with the sowing of chickpeas. In year 2, this percentage increased to 68%. In other treatments, nodula-

Table 3. Dry matter (kg ha^{-1}), grain yield (kg ha^{-1}), grain protein (%), and protein yield (kg ha^{-1}) of chickpeas with and without soil solarization and *Rhizobium* inoculation

Treatment	Year 1				Year 2			
	Dry matter	Grain yield	Grain protein	Protein yield	Dry matter	Grain yield	Grain protein	Protein yield
Solarized								
SCP	1830	1190	13.5	159	3970	2110	15.8	405
CP	1780	1160	14.1	164	3940	2020	16.0	392
C	1550	1000	13.6	137	3980	2110	15.6	401
Non-solarized								
SCP	2040	1340	14.7	197	3660	2020	15.7	388
CP	2050	1360	14.9	202	3810	1980	15.8	381
C	1800	1190	14.3	170	3660	1960	15.6	373
±SE	71	49	0.36	8.9	116	65	0.23	14.9
CV (%)	9	10	6	13	7	8	4	9

See footnote a to Table 1

tion obtained with the inoculant strain decreased from 6.2%–13.2% in year 1 to 1.9%–9.3% in year 2 (Table 1).

Previous unpublished studies (O.P. Rupela, M.R. Sudarshana, and R. Gururaja) indicated that after a considerable reduction in the native chickpea *Rhizobium* population in solarized plots, the numbers continued to increase even in the absence of the chickpea host. It was for this reason that we decided to introduce the inoculant strain into the soil as early as possible. Sowing a sorghum cover crop provided a good vehicle for the application and spread of the inoculant strain in soil. Chickpea rhizobia are known to survive well and even multiply in the rhizosphere of sorghum (Toomsan et al. 1983). Thus the inoculant strain may have become established in large numbers before the chickpeas were sown about 4 months later. The MPN of native chickpea *Rhizobium* in the non-inoculated plots increased from $<10\ g^{-1}$ soil soon after the solarization to $1.3-2.0\times10^2\ g^{-1}$ soil at the time the chickpeas were sown (within about 4 months). This increase obviously occurred in the sorghum rhizosphere. With inoculation following solarization, the increase over the same period was about 28-fold over the non-inoculated treatment, and was reflected in the increased number of nodules formed by the inoculant strain in this treatment. The inoculant strain, when first introduced with the chickpeas 4 months after the solarization, thus faced a large native population and succeeded in forming only 13% of the total possible nodules. This effect was observed in spite of the application of a high population of the inoculant strain using the liquid inoculation method, which is considered a superior method of *Rhizobium* application (Brockwell et al. 1980).

In year 2, the percentage nodulation obtained with the inoculant strain was also high (68.3%) when it was introduced soon after solarization. Where the inoculant was introduced about 4 months after solarization, the success of the inoculation remained very poor (<10% nodules). Clearly, the inoculant strain became well established and had even survived well for at least one year when it was measured. These measurements were continued beyond the present study.

In the solarized plots most of the 47% nodulation obtained with dual inoculation was apparently formed by the rhizobia applied with the sorghum, because the inoculant rhizobia applied when the chickpeas were sown formed only 13% nodules. This indicates that resident rhizobia, whether indigenous or introduced (established by special methods such as solarization), are likely to form the most nodules on the host. This may be attributed to the special advantage of resident rhizobia in making contact with the rhizosphere in large numbers. A further increase in nodulation by the inoculant strain, from 47% in year 1 to 68% in year 2, probably reflects rhizosphere multiplication of the inoculant strain in year 1 chickpeas and also those rhizobia that originated from year 1 degenerating nodules.

The reduction in native rhizobia by soil solarization and the successful establishment of inoculant *Rhizobium* as demonstrated in these studies indicates that solarization can be used as a new research tool to evaluate inoculant strains for N_2 fixation without confounding their ability to compete. Several inoculant strains can now be introduced to field soils (with a high native population of homologous rhizobia) after solarization and compared for their survival, persistence, and effectiveness under field conditions.

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7.3 PA 85/21 Survival of introduced *Rhizobium* in an Alfisol (OPR, JVDKKR)

Introduction

This trial was started in 1984/85 to test a hypothesis that resident rhizobia, be they native or introduced, have a spatial advantage and form more nodules than the inoculant strain introduced fresh in the given year. For the previous two years report see Chickpea Agronomy, Progress No.1, pp 139-143. This section reports on the work done in 1986/87.

Materials and Methods

Six treatments in randomized block design with five replications in different years were as follows:

Treatment	1984/85	1985/86	1986/87
T1	Control	Control	Control
T2	Control	Liquid, H45	Liquid IC 59
T3	Control	Seed coated, H 45	Seed coated IC 59
T4	Seed coated H 45	Seed coated, IC 2091	Control
T5	Seed coated H 45	Seed coated, IC 2091	Seed coated IC 59
T6	Seed coated H 45	Control	Control

Sowing was done on 29 October 1981 in 30 x 10 cm spacing followed by a postsowing irrigation the next day. The plot size per treatment was 5.5 x 3.9 m.

At 77 DAS six plants per plot were sampled twice per plot. Nodules from one set of six plants were removed and stored in 2% glycerol at $-13^{o}C$ in a deep freezer. Another set of 6 plants per plot was used for assessing nodule number, nodule mass, shoot mass, and ARA (acetylene reduction activity). Final harvesting was done on 23 February 1987 when total dry matter and grain yield was measured.

Results and Discussion

Nodulation and N_2-fixation in this year was much lower than in the previous year (see Chickpea Agronomy, Progress Report No.1 pp 139-143) when measured at 77 DAS the (Table 7.3.1). Last year it was measured at 43 DAS and perhaps by 77 DAS the ARA had greatly reduced. However, the reasons for low nodule no. and mass are not clear. Available-P was low (2.8 mg kg^{-1}) even in 1985/86 and this year it was <1 mg kg^{-1} soil in three replicate plots that were measured. This could be a reason for low nodulation. The dry matter and grain yield was, however, similar to that of last year and the treatment differences were absent (Table 7.3.1). Mineral-N level was 18 mg kg^{-1} soil in the top 15 cm profile and we expected treatment differences but it seems that with frequent sprinkler irrigations (once every 10-12 days, total 9 irrigations) the plants could meet their N-needs satisfactorily.

It seems that after growing chickpea continuously for 2-3 years the very low native population of rhizobia multiplies to the level of inoculated plots. This discouraged serotyping of nodules, which was deferred to a later date.

Table 7.3.1. Plant growth, nodulation, total dry matter and grain yield as affected by different time and method of *Rhizobium* application, RCE-4, postrainy season 1986/87, ICRISAT Center.

Rhizobium	At 77 DAS					At final harvest	
Inoculation treatment	Nodule no. $plant^{-1}$	Nodule dry mass(mg $plant^{-1}$)	Shoot dry mass (g $plant^{-1}$)	ARA (um $plant^{-1}$ h^{-1})	ARA (uM g^{-1} dry nod. mass)	Total dry matter (t ha^{-1})	Grain yield (t ha^{-1})
T1	10	166	7.1	0.5	4.4	2.82	1.50
T2	8	32	7.0	0.2	3.7	2.79	1.46
T3	6	30	5.1	0.1	2.0	2.41	1.25
T4	11	120	6.0	0.6	4.4	2.91	1.54
T5	15	109	6.5	0.5	8.5	3.33	1.70
T6	7	50	5.2	0.3	5.3	2.29	1.16
SE	±3.2	±41.3	±1.06	±0.12	±1.84	±0.322	±0.195
F-test	NS	NS	NS	*	NS	NS	NS
CV%	75	110	39	77	88	26	30

7.4 PA 86/48 Rates of *Rhizobium* application and response to inoculation (OPR)

Introduction

Previous studies have shown that response to *Rhizobium* application for increased yield was generally seen when native rhizobia were lacking. About 10^6 rhizobia per seed were generally applied in these trials. Increased nodulation and/or plant growth has been reported for groundnut, soybean and chickpea when a high population of rhizobia per seed was applied in pot culture conditions. In the postrainy season of 1985/86 increase in nodule number was recorded at ICRISAT Center when at least 10^7 rhizobia were applied per seed in a field trial in Alfisol. This is a similar trial conducted in the postrainy season 1986/87 in three Vertisol fields one with high and two with low native chickpea *Rhizobium* population.

Materials and Methods

The trial was conducted in 6 x 6 latin square design in three fields BP 2C, having at least 1000 rhizobia, BIL 6E having <10 rhizobia, and BIL 6H having low but variable population of chickpea rhizobia that ranged 5 to 457 rhizobia g^{-1} soil in a triplicate measurement at the time of sowing chickpea. The other properties of soils of these three fields are listed in Table 7.4.1. Lands were prepared in summer after applying 240 kg ha^{-1} of single super phosphate and left undisturbed during the rainy season. Weeds were occasionally removed manually during June to October 1986. Chickpea genotype K 850 (ICC 5003) was sown on 29 October 1986 in BP 2C at 30 x 10 cm spacing, on 11 November in BIL 6E at 60 x 10 cm spacing and on 12 November in BIL 6H at 60 x 10 cm spacing. A dibler allowing uniform sowing depth of 7.5 cm was used at sowing. Twenty ml $seed^{-1}$ of liquid suspension of peat in water was applied at sowing. The concentrated suspension for T_6 was prepared by suspending 100 g peat of strain IC 59 L^{-1} of water. Suspension for other treatments were prepared by 100 fold sequential dilutions from T_6 down to T_2. Ordinary water was used for T_1. The count of rhizobia applied (at highest level of T_6) per seed (in the 20 ml) was 1.8 x 10^8 in BP 2C, 1.6 x 10^8 in field BIL 6E and 1.2 x 10^8 in field BIL 6H. For field BP 2C, we thus applied 1.8 x 10^6 rhizobia per seed in T_5, 1.8 x 10^4 rhizobia per seed in T_4, 1.8 x 10^2 rhizobia per seed in T_3 and 1.8 rhizobia per seed in T_2. Similarly, the count per seed applied for the other two fields can be calculated.

No postsowing irrigation was provided except in BP 2C that was flood irrigated soon after sowing. Nodulation and plant growth observations were made on a subsample of 12 plants $plot^{-1}$ in BP 2C at 50 DAS, four plants $plot^{-1}$ in BIL 6E at 51 DAS and 64 DAS and on four plants $plot^{-1}$ in BIL 6H at 64 DAS and 74 DAS.

All the nodules were preserved after taking fresh nodule mass on different sampling dates for all these three fields. A representative sample for serotyping of nodules of 50 day sampling of BP 2C, 64 day sampling of BIL 6E and BIL 6H from a given treatment plot was determined by the formula (N x 100)/(N + 100) where N = total no. of nodules on sampled plants. Final harvesting was done from 1.8 m^2 $plot^{-1}$ on 11.2.87 in field BP 2C from 7.2 m^2 $plot^{-1}$ on 24.2.87 in field BIL 6E and from 1.8 m^2 $plot^{-1}$ on 25.2.87 in field BIL 6H.

Results and Discussion

Analysis of soil from the three fields suggested that the three fields had similar pH, EC, and total-N. Olsen-P values seem low but in the past we have not recorded any response to applied P even at these levels. Still 240 kg ha^{-1} of single superphosphate was applied at land preparation. Available-N in BIL 6E and BIL 6H was at least twice in that of BP 2C (Table 7.4.1). At the N-concentration of BP 2C, N- deficiency symptoms were observed in the Nod^{-} line at about 50 DAS that were growing in the adjoining plots of field BP 2C. (see section 6.4 on trial PA 86/47 in this report). Nodulation of K 850 at all the rates of Rhizobium application in field BP 2C was similar (Table 7.4.2). But in field BIL 6E and BIL 6H nodule no $plant^{-1}$ greatly improved (Tables 7.4.3, 7.4.4) when at least 10^6 rhizobia were applied per seed. Improvement in nodule mass was only recorded in field BIL 6E having < 10 rhizobia g^{-1} soil but not in field BIL 6H that had over 100 rhizobia g^{-1} soil in some of the replicate plots. This suggested that a good number of nodules were formed by native rhizobia. The size of nodules formed on 50 days old plants in BP 2C was about 8-10 fold bigger than the 51 day old plants of BIL 6E. High available-N in BIL 6E seems to be a plausible reason for the poor nodule development (see section 6.4 on trial PA 86/47 in this report). The great improvement in nodule number due to inoculation in T_5 and T_6 of both the field BIL 6E and BIL 6H did not result in improved shoot growth measured at 51 DAS and 64 DAS in BIL 6E and at 64 DAS and 74 DAS in BIL 6H. Obviously the high soil-N allowed the plants to meet its N-demand from soil and masked the possible inoculation effects in BIL 6E and BIL 6H. In field BP 2C the treatment effect on nodulation was absent and therefore its effect on shoot mass was not expected.

A maximum of 8% nodules were formed by the inoculant strain at highest concentration (T_6) in field BP 2C having at least 10^3 native rhizobia. This suggests that the strain IC 59 could not complete the native rhizobia. Even in field BIL 6H that had portions of land with at least 100 rhizobia g^{-1} soil IC 59 formed 68% nodules at T_6. But in field BIL 6E which was practically devoid of native rhizobia, IC 59 formed maximum (92%) nodules at T_6. It was surprising to note that even in BIL 6E only 27% nodules were formed at T_4 receiving 1.2 x 10^4 rhizobia per seeds, through liquid application which is considered the best method of Rhizobium application. This implies that for reasonable success of inoculation at least 10^9 rhizobia per seed should be applied.

There was no treatment effect on total dry matter and grain yield at final harvest in any of the three fields. It may be because of no nodulation response in BP 2C and in fields BIL 6E and BIL 6H it may be due to high mineral-N in soil that perhaps masked the nodulation effect (Tables 7.4.2-7.4.4).

The last two fields produced around 2 t ha^{-1} dry matter and 1.0 t ha^{-1} grains while in BP 2C at least 3 t ha^{-1} dry matter and 1.7 t ha^{-1} grain was produced. It may be due to additional water provided with the postsowing irrigation and about 36 mm rain the trial in BP 2C received at 11 DAS. The trial in BIL 6E and BIL 6H was sown on 11 Nov 1986 and only about 10 mm rain fell until harvest.

Poor nodulation in field BIL 6E even at T_6 was intriguing. It was not explained by the soil moisture at sowing that was good and ranged from 23 to 28% in the top 30 cm profile at sowing. Such levels in previous trials resulted in good nodulation (see ICRISAT 1985, ICRISAT Annual Report 1984 pp 143-144). It was suspected that the rhizobia died in due course after application. To understand this, soil cores were collected at 102 DAS at growing points when plants were still green but physiologically mature. Roots and nodules were carefully discarded and the soil was subjected to MPN count using the method of Toomsan et al (1984). Data in Table 7.4.5 is not very conclusive because of low counts in T_5. If we take the weight of soil core (40 mm diam. x 15 cm) as 400 g and assume that most of the applied rhizobia remained in the vicinity where applied suggested a great decrease in the count over time. Normally one would expect an increase in count due to rhizosphere multiplication but instead we recorded a 10 fold decrease at T_6 and a 100- to 1000-fold decrease at T_5. At T_4 and at lower levels to T_2 there was no appreciable change or a 2 to 3-fold increase in population was noticed. Non-inoculated control treatment plots showed a 10-100 fold increase.

In conclusion, the inoculant strain IC 59 failed to establish in Vertisol having at least 1000 rhizobia g^{-1} soil even when an extremely high inoculation rate was used. In soil having variable population of native rhizobia but always less than 1000 rhizobia a maximum of 68% nodules were formed by IC 59. But in a soil of uniformly low native rhizobia (<10 g^{-1} soil) about 92% nodules were formed by IC 59. Even in this field (BIL 6E) only 27% nodules were formed at the usually recommended population of 10^4 rhizobia per seed. This suggests that even the low number of native rhizobia multiply faster and form nodules than the 10^4 rhizobia of the inoculant. One plausible reason of low success may be the rainfed conditions. Rhizobia applied in the seed zone may remain where it is applied and may not move further in the absence of additional infiltrating water that could carry these rhizobia deeper into the active root zone.

Toomsan, B., Rupela, O.P., Mittal, S., Dart, P.J., and Clark, K.W. 1984. Counting *Cicer* - *Rhizobium* using a plant infection technique. Soil Biology and Biochemistry 16:503-507.

Table 7.4.1. Soil properties and rhizobial population used per seed at sowing trial PA 86/48, ICRISAT Center postrainy season 1986/87

Parameter	BP 2C	BIL 6E	BIL 6H
pH	8.16	8.29	8.26
EC (dS m^{-1})	0.27	0.25	0.20
Available-P (mg kg^{-1} soil)	6.5	4.0	1.8
Organic carbon (%)	1.36	0.89	0.77
NO_3-N (mg kg^{-1} soil)	6.2	19.6	18.2
NH_4-N (mg kg^{-1} soil)	7.3	6.5	8.2
Available-N (mg kg^{-1} soil)	12.5	26.1	26.4
Total-N (mg kg^{-1} soil)	528	553	505
Chickpea rhizobia g^{-1} soil	4.82×10^3	5-10	5-457
Inoculant count (per seed) used at T_6	1.8×10^8	1.6×10^8	1.2×10^8

Table 7.4.2. Plant growth, nodulation, total dry matter and grain yield of chickpea as affeced by different rates of Rhizobium application, postrainy season, BP 2C, ICRISAT Center 1986/87.

Treatment	At 50 DAS				At final harvest		
	Nod no. $plant^{-1}$	Nodule fresh mass (g $plant^{-1}$)	Shoot dry mass (g $plant^{-1}$)	% Nod. from Inoculant	Total dry matter (t ha^{-1})	Grain yield (t ha^{-1})	No. plants m^{-2}
T1	93	2.6	5.2	0(0)	3.19	1.78	28
T2	98	2.8	4.9	0(0)	3.32	1.81	25
T3	99	2.9	5.2	0(0)	3.11	1.77	26
T4	101	2.8	4.7	1(5)	3.37	1.89	28
T5	96	2.7	4.7	6(14)	3.09	1.73	26
T6	91	2.6	5.4	8(15)	3.24	1.84	27
SE	±4.5	±0.19	±0.28	(±1.6)	±0.119	±0.055	±1.1
F-test	NS	NS	NS	NS	NS	NS	NS
CV%	12	18	14	70	9	8	10

Note: Data in parantheses are angular transformed values.

Table 7.4.3. Plant, nodulation, total dry matter and grain yield of chickpea as affected by different rates of *Rhizobium* application, postrainy season 1986/87, BIL 6E, ICRISAT Center.

Treatment	At 51 DAS: Nodule no. $plant^{-1}$	At 51 DAS: Nodule fresh mass ($mg\ plant^{-1}$)	At 51 DAS: Shoot dry mass ($g\ plant^{-1}$)	At 64 DAS: Nodule no. $plant^{-1}$	At 64 DAS: % Nod. from IC 59	At 64 DAS: Nod. fresh mass ($mg\ plant^{-1}$)	At 64 DAS: Shoot dry mass ($g\ plant^{-1}$)	At final harvest: Total dry matter ($t\ ha^{-1}$)	At final harvest: Grain yield ($t\ ha^{-1}$)
T1	1	1	2.8	2	0(0)	4	4.5	2.12	1.07
T2	1	2	2.7	1	8(8)	5	5.9	2.06	1.02
T3	2	4	2.5	2	9(12)	4	5.0	1.86	0.91
T4	4	10	2.3	4	27(31)	14	4.6	1.80	0.88
T5	16	34	2.4	27	75(60)	172	5.8	1.70	0.86
T6	19	59	3.2	26	92(74)	117	5.4	1.90	0.98
SE	±1.9	±9.7	±0.34	±1.7	(±4.3)	±18.2	±0.65	±0.125	±0.079
F-test	***	**	NS	***	(***)	***	NS	NS	NS
CV%	69	130	31	41	(34)	85	31	16	20

Table 7.4.4. Plant growth, nodulation, total dry matter, and grain yield of chickpea as affected by different rates of *Rhizobium* application, postrainy season 1986/87 BIL 6H, ICRISAT Center.

Treatment	At 64 DAS				At 74 DAS			At final harvest	
	Nod. no plant^{-1}	% Nod. from IC 59	Nod. fresh mass (mg plant^{-1})	Shoot dry mass (g plant^{-1})	Nod. no. plant^{-1}	Nod. fresh mass (mg plant^{-1})	Shoot dry mass (g plant^{-1})	Total dry matter (t ha^{-1})	Grain yield (t ha^{-1})
T1	7	0(0)	54	5.0	8	20	9.1	2.07	0.97
T2	10	3(6)	38	4.7	9	50	9.4	2.33	0.97
T3	10	3(7)	16	5.3	9	25	9.8	2.17	1.00
T4	11	18(25)	11	5.5	7	16	9.9	2.28	1.03
T5	23	54(47)	54	5.6	15	54	9.0	2.24	1.08
T6	20	68(56)	28	5.1	17	53	7.9	2.30	1.07
SE	±2.0	(±3.0)	±24.6	±0.36	±1.7	±17.7	±0.71	0.117	±0.063
F-test	***	(***)	NS	NS	**	NS	NS	NS	NS
CV%	36	(31)	180	17	40	120	19	13	13

Note: Data in parentheses are angular transformed values

Table 7.4.5. Soil moisture (%) over profile at sowing chickpea and chickpea rhizobia in BIL 6E at 102 DAS, postrainy season 1986/87, ICRISAT Center.

Depth (cm)	Soil moisture (%) at sowing (Mean of 3 reps)	Treatment	Rhizobia g^{-1} soil at 102 DAS: Log values	Nos.	Rhizobia per core of 400 g
0-15	22.8 (22.5)	T1	0.6	4	1.7×10^2
15-30	26.1 (30.7)	T2	0.5	3	1.3×10^2
30-45	28.5 (32.3)	T3	0.5	3	1.3×10^2
45-60	31.1 (33.9)	T4	2.1	123	4.9×10^4
60-75	33.5 (35.4)	T5	1.3	20	8.2×10^3
75-90	33.8 (35.5)	T6	4.4	26920	1.1×10^7
90-105	33.1 (35.1)				
105-120	32.3 (34.6)				
120-135	31.7 (34.2)				
135-150	31.5 (34.1)				
150-165	28.3 (32.1)				
165-180	27.9 (31.8)				
SE	(±1.08)		±0.61		
F-test	**		**		
CV%	6		67		

Note: Data in parentheses are angular transformed values.

8. [illegible]-114(86)IC Maintenance, multiplication and distribution of rhizobial germplasm of chickpea and pigeonpea.

8.1 Objectives

a) To develop an efficient system for classification, and storage, of chickpea and pigeonpea <u>Rhizobium</u> strains.

b) To develop an efficient procedure of multiplying, packaging and despatching strains from this collection.

8.2 Maintenance of rhizobial strains their multiplication and supply to NARS (OPR)

Multiple copies of each of 47 rhizobial strains were freeze dried after authentication. The strains were IC 51, -54, -99, -110, -113, -114, -116, -121, -133, -148, -158, -161, -162, -163, -164, -2002, -2005, -2007, -2009, -2011, -2016, -2021, -2027, -2034, -2046, -2048, -2049, -2051, -2053, -2054, -2056, -2057, -2063, -2064, -2066, -2070, -2073, -2075, -2079, -2085, -2089, -2092, -2093, -2095, -2104, -2105, and -2107.

About 15 inoculant packets each of the 21 rhizobial strains listed in Table 8.2.1 were prepared and supplied to thirteen locations of the All India Coordinated Pulses Improvement Program for multilocation trials. We did not subject these inoculants to plant infection count but all the inoculants were nodulation positive up to 10^8 dilution.

In addition, rhizobial strains as ampoules/agar slopes and peat inoculants were supplied on request. Some of these are listed in Table 8.2.2. Soil samples were also received from some NARS for determining plant infection most probable number counts (Table 8.2.3).

Table 8.2.1. Plate count of peat inoculant prepared in 1986/87.

S.No.	*Rhizobium* strain	Plate count (no. g^{-} peat)
1	IC 149	3.4×10^{9}
2	CM 1	6.4×10^{9}
3	IC 76	1.4×10^{9}
4	KG 46	9.5×10^{9}
5	TAL 480	1.4×10^{9}
6	IC 2018	5.8×10^{9}
7	TAL 620	2.0×10^{9}.
8	KG 31	4.2×10^{9}
9	G 567	1.3×10^{10}
10	TAL 1148	1.8×10^{10}
11	G-5-81	4.2×10^{9}
12	CBH-32	1.0×10^{9}
13	IC 94	1.3×10^{10}
14	F 6	8.9×10^{8}
15	Ca 181	3.1×10^{10}
16	F 75	4.9×10^{9}
17	KG 61	1.3×10^{9}
18	IC 59	2.4×10^{8}
19	G-10-80	ND
20	IC 53	ND
21	B-1	ND

ND = Not determined

Table 8.2.2. Chickpea rhizobial strains and inoculants supplied during May 1986 to June 1987.

Person	Place	Strain	Remarks
India			
Dr K.R. Chowgule	Bombay	IC 76	Agar slope
Assoc. Prof of Breeding	NARP Bharuch, Gujarat	IC 59 IC 76	Agar slopes
Soil Microbiologist	Rajandra Agril. Univ. Sabour, Bihar	IC 76 IC 172	Agar slopes
Dr A.L. Khurana	HAU, Hisar	CM-1	Agar slope
Dr S.C. Bhandari	Sukhadia Univ. Jobner Rajasthan	IC 59 IC 76 IC 172	Agar slope
Dr Dulare Lal	Regional Soil testing lab. Lucknow	IC 76	Agar slope
Dr M.M. Husain	APAU Hyderabad	IC 59	Inoculant
Mr D.D. Dom	Karnataka	IC 59, IC 2099	Agar slope
Dr Banshi Dhar	Varnasi, U.P.	IC-76, IC-128 IC-2002, IC-2048 IC-2072, IC-2096 IC-2098, IC-2099 IC-2100, IC-2104	Agar slope
Abroad			
Dr Nora B. Inciong	Philippines	IC 59, IC 76	Both as agar slopes and as ampoules
Mr Tae-San Kim	South Korea	IC 59	Inoculant
Dr P.J. Dart	Australia	IC 59, IC 76, IC 165, IC 172	Ampoules
Dr Uttla Than	Burma	IC-53, IC-59, IC-76, IC-149, IC-2018, IC-2099	Agar slopes

Table 8.2.3. Plant infection MPN count done in 1986/87 for NARS

Requestee	Sample no.	Plant infection MPN-count g^{-1} dry soil or inoculant	Remarks
Hindustan lever	A	< 10	Inoculants
	B	< 10	
Agril. Res. Station, Sehore	1	40	Soil sample
	2	91	Soil sample
Gujarat Agril. Univ. S.K. Nagar	1	<10	Soil sample
	2	41	Soil sample
Dr Chandra G.B. Pant Univ. Res. Stn. Nagina	1	3.9×10^2	Soil sample

9. CP-115(85)IC Detection and alleviation of mineral nutrient deficiencies and soil chemical toxicities in chickpea and pigeonpea.

9.1 Objectives

a) To develop appropriate methodology for detecting mineral nutrient deficiencies in chickpea and pigeonpea.

b) To develop appropriate corrective measures for any mineral nutrient limitations found.

c) To detect genotypic differences in response of chickpea and pigeonpea to salinity and alkalinity.

d) To identify mechanisms of resistance to salinity and alkalinity damage so as to further enhance the screening procedure.

9.2 PA 86/35 Screening Vertisol, Entisol and Inceptisol soils for potential nutrient limitations to chickpea cultivar K 850 by means of a pot culture technique (CJ, NPS).

Introduction

This technique was tried last year for chickpea cultivar ICCC 35 in an Alfisol and Vertisol. While the technique proved to be satisfactory for the Alfisol, plant growth in the Vertisol was generally poor. Excess soil moisture conditions were suspected to be reducing growth, even though the Vertisol was kept at field capacity. Optimum soil moisture level for growth of chickpea in Vertisol was determined before conducting the present experiment (see Section 5.2).

Thus it was intended to repeat the screening with an ICRISAT Vertisol, using an optimum soil moisture level, as well as test soil typical of the ICRISAT subcenters at Hisar and Gwalior. These studies will contribute to production of a research bulletin on identification of adaphic limitations in chickpea and pigeonpea.

Materials and Methods

Treatments were assigned as follows:

Factor	Nutrient
A	P
B	S
C	K
D	Zn
E	Fe
F	B
G	(Mo, Co, Mn, Cu)

Details of nutrient amount and form applied are given in Table 9.2.1. The experimental design was a $1/2 \times 2^7$ factional confounded into 4 blocks as follows:

Treatment No.	BLOCK I	II	III	IV
1	ABCDEFG	ABCEF	ABCFG	ABCDF
2	ABCDE	ABCEG	ABDEF	ABCDG
3	ACEFG	ABDFG	ABDEG	ABEFG
4	BDEFG	ACDEF	ACDFG	CDEFG
5	CDF	ACDEG	BCDEF	ADEFG
6	CDG	BCDFG	BCDEG	BCEFG
7	EFG	ABD	ABC	CDE
8	ABF	CFG	CEF	ABE
9	ABG	DEF	CEG	ACF
10	ACE	DEG	DFG	ACG
11	ADF	AFG	ACD	ADE
12	ADG	BCD	AEF	BCE
13	BCF	BEF	AEG	BDF
14	BCG	BEG	BFG	BDG
15	BDE	A	D	F
16	E	C	B	G

Blocks are confounded on the basis of the three factor interactions (ACE), (BDE) and (EFG) being unlikely to occur. For further details refer to W.G. Cochran and G.M. Cox (1957). "Experimental Designs", 2nd Ed. Wiley: New York. Separate experiments were conducted for Vertisol (ICRISAT Center), Entisol (Hisar) and Inceptisol (Gwalior) .

For the general procedure followed in such experiments, refer to pp. 162-164 in Chickpea Agron. Prog. Rep. No.1. Vertisol was collected from the Pulse Agronomy soil pit in BR 4 and Entisol and Inceptisol from recently unfertilized and uncropped areas in the vicinity of ICRISAT experimental areas at Hisar, and Gwalior, respectively. Four kg of air-dried soil from each site, sieved to 5 mm, was added to pots. Pots had 20 cm top diameter, 14.5 cm base diameter and were 18 cm deep. They were lined with water-tight plastic bags. Nutrients were added on 10 Nov. and the experiment sown on 11 Nov. Seeds of K 850 were treated with "clorax" and placed in 6 holes at a depth of 2-3 cm. Rhizobium strain IC 76 was inoculated as a slurry at 10^8 rhizobia/seed. 400 ml deionized water was then added to each pot of the Vertisol and 300 ml each to the other soils.

The experiment was conducted in Glasshouse 3, Bay 1 where daily average max/min temperatures ($\pm$SE) during the experiment were 23.5 $\pm$ 0.35/15.3 $\pm$ 0.30^{o}C. 150 g polypropylene beads were added to each pot at 11 DAS. Pots were kept weed free and chickpea seedlings gradually thinned to 3 plants per pot by 15 DAS.

Water content of pots was gradually increased to reach field capacity (FC) by 13 DAS (FC = 34.3% for Vertisol, 13.0% for Entisol and 17.7% for Inceptisol). Thereafter, pots were maintained at FC. Pots were rerandomized at about 10 day intervals.

The experiment was harvested on 6 Jan 1987 (56 DAS) when stems were cut at the soil surface and the roots carefully washed out of each pot. Shoot and root (including nodules) samples were oven-dried and weighed.

Results and Discussion

From 13 DAS it was observed that seedling growth vigor was in the order Inceptisol > Entisol > Vertisol. A week later, however, growth in the Entisol was matching that in the Inceptisol and thereafter growth in the Entisol was more. By 30 DAS, slight P responses were noticed in Entisol and Inceptisol and large P and S responses and interaction in the Vertisol. Flowering initiated in each soil type at 30 DAS.

At harvest, the large P and S responses and interaction in shoots of Vertisol were recorded (Table 9.2.2). There were also significant interactions of P and S with K, with +K reducing growth at -P and -S. This may have been a toxicity effect of KCl. This depressive effect of K was also measured in roots, along with a S response but not a P response.

In Inceptisol, there was also a slight P x S interaction in shoots but only the main effect of P was significant (Table 9.2.2). There were also slight interactions of K x Zn, K x Fe and Zn x Fe. In roots, the P response was also significant and there was a minor Fe x B interaction.

In Entisol, a marginal P response was recorded in shoots (Table 9.2.2). There was also a depressive effect of K on root growth, and an interaction with Zn. This was perhaps due to toxicity of KCl.

Overall, it may be concluded that P and S can be severe limitations to chickpea growth in Vertisol and only marginal P responses can be expected in Inceptisol and Entisol.

Table 9.2.1. Details of basal nutrient additions for pot experiment PA 86/35

Salt	M.W.	Nutrient element (kg/ha)	Nutrient element (mg/pot)	Salt (mg/ pot)	g salt/ vol. stock	mL stock/ pot
1. K_2SO_4	174.26	50 K 20 S	157.15	350.15	280.1/4 L	5.0
2. Na_2SO_4 (for -K treatments only)	142.04	20 S	64.45	285.54	28.55/ 500 mL	2.5
3. KCl (for -S treatments only)	74.55	50 K	157.15	299.65	29.97/ 250 mL	2.5
4. $ZnCl_2$	136.29	2.5 Zn	7.86	16.38	16.38/2 L	2.0
5. $CuCl_2.2H_2O$	170.50	2.5 Cu	7.86	21.06	21.06/2 L	2.0
6. H_3BO_3	61.83	0.5 B	1.572	8.979	8.979/2 L	2.0
7. $Na_2MoO_4.2H_2O$	241.98	0.15 Mo	0.471	1.188	1.188/2 L	2.0
8. $FeC_6H_5O_7.5H_2O$	335.03	2.5 Fe	7.86	47.14	47.14/2 L	2.0
9. $MnCl_2.4H_2O$	197.91	2.5 Mn	7.86	28.31	28.31/2 L	2.0
10. $CoCl_2.6H_2O$	237.95	0.1 Co	0.314	1.269	1.269/2 L	2.0
11. $Ca(H_2PO_4)_2.H_2O$	252.08	100 P 65 Ca	314.3 20.43	1278		

N.B.: a) Conversion of kg/ha to mg/pot. Area of 20 cm diameter pot = 0.03143 m2

$$\frac{0.03143}{10,000} \times 1,000,000 = \underline{3.143 \text{ mg/pot} \equiv 1 \text{ kg/ha}}$$

b) Make up each solution separately (apart from Co, Mn and Cu which may be combined)

c) Make up fresh solution of Fe citrate for each experiment and store in refrigerator.

Table 9.2.2. Significant main effects and interactions of nutrient treatment effects on K 850 grown in pots of Vertisol, Inceptisol and Entisol, Nov 1986 - Jan. 1987.

Vertisol

Shoot dry weight (g/plant)

	-P	+P	Mean
-S	0.887	1.077	0.982
+S	1.436	4.221	2.828
SE	±0.0484***		±0.0342***
Mean	1.161	2.649	
SE	±0.0342***		

	-P	+P	Mean
-K	1.218	2.564	1.891
+K	1.105	2.734	1.919
SE	±0.0484**		±0.0342
Mean	1.161	2.649	
SE	±0.0342***		

	-S	+S	Mean
-K	1.051	2.730	1.891
+K	0.913	2.928	1.919
SE	±0.0484**		±0.0342
Mean	0.982	2.828	
SE	±0.0342***		

Root dry weight (g/plant)

-S	+S	SE
1.641	2.178	±0.0466***

-K	+K	SE
1.988	1.831	± 0.0466*

Inceptisol

Shoot dry weight (g/plant)

	- P	+P	Mean
-S	3.338	4.395	3.866
+S	3.511	4.216	3.863
SE	±0.0737*		±0.0521
Mean	3.424	4.305	
SE	±0.0521***		

	-K	+K	Mean
-Zn	3.823	3.988	3.905
+Zn	3.902	3.746	3.842
	±0.0737*		±0.0521
	3.862	3.867	
	±0.0521		

	-K	+K	Mean
-Fe	3.766	3.923	3.844
+Fe	3.959	3.811	3.885
SE	±0.0737*		±0.0521
Mean	3.862	3.867	
SE	± 0.0521		

	-Zn	+ Zn	Mean
-Fe	3.977	3.712	3.844
+Fe	3.834	3.936	3.885
	± 0.0737*		±0.0521
	3.905	3.842	
	± 0.0521		

Root dry weight (g/plant)

-P	+P	SE
1.502	1.561	±0.0451*

	-Fe	+Fe	Mean
-B	1.637	1.494	1.566
+B	1.529	1.664	1.597
SE	± 0.0637*		±0.0451
Mean	1.583	1.579	
SE	± 0.0451		

Entisol

Shoot dry weight (g/plant):

-P	+P	SE
4.355	4.737	±0.0540***

Root dry weight (g/plant)

	-K	+K	Mean
-Zn	2.249	1.891	2.070
+Zn	2.093	2.096	2.094
SE		±0.0803*	±0.0568
Mean	2.171	1.993	
SE		±0.0568*	

9.3 PA 86/37 Mini-NP trials for chickpea (CJ, NPS, OPR)

Introduction

Debate continues on the needs, or otherwise, for phosphorus and nitrogen fertilizer and rhizobial inoculation for chickpea. For breeders' yield trials in particular it is important to know the nutritional status of the crop, so as to appropriately interpret genotype x environment interactions. In fact, for any experimentation it is necessary to know whether or not the crop is limited by inadequate nutrient supply, and the extent of this limitation.

Standard "need to inoculate" trials have been used as a matter of course in legume experimentation for many years. It is surprising that they have not been regularly used in legume research at ICRISAT. These consist basically of three treatments: not inoculated, inoculated with the best known effective rhizobial strain, and inoculated plus nitrogen fertilizer (to measure the effectiveness of the symbiosis). Where there is uncertainty about soil phosphorus status, it is wise to include a fourth treatment: inoculation without phosphorus, with the other three treatments receiving a basal dose of phosphorus (where other nutrient deficiencies are suspected then additional treatments could also be included).

Such trials were established on pigeonpea breeders fields in 1986, around the edges of precision fields as fertilizer treatments are not allowed to be imposed within the main cropping area of these fields. It was proposed to set up a similar series of trials on fields where chickpea breeders have their yield trials, at ICRISAT Center, Hisar and Gwalior, as well as on Chickpea Agronomy fields.

Materials and Methods

Treatments were as follows:

1. P as 200 kg/ha SSP (-*Rhizobium*)
2. P + *Rhizobium* (IC 76) inoculation
3. P + *Rhizobium* + N as 60 kg/ha urea at sowing and a further 100 kg/ha urea during vegetative growth (when top soil is moist due to rain or irrigation).
4. *Rhizobium* (-P)

A randomized block design was used with adjacent plots of 4 treatments placed at different parts of the edges of fields. These parts of the fields were not fertilized in the current season. Plant spacing was 30 x 10 cm, with plots consisting of 4 rows 30 cm apart and 4 m long. Dummy border rows were sown where a plot row faced an edge. Apart from fertilizer application, plants were given optimum conditions of irrigation and pest, disease and weed control, as far as was known and could be arranged. *Rhizobium* was slurry-inoculated and basal fertilizer placed at about 10 cm in the seed row. Seeds were sown at about 5 cm depth. For the later N application urea was placed in furrows at least 5 cm deep between chickpea rows. At harvest, only the two inner rows were considered for yield estimation. Other locational and cultural details are as follows:

Site		Sown	Reps	Post-sowing irrigation	Genotype	Veg. phase urea application
IC	BP6A	21/10/86	4	24/10	Annigeri	25/11
	BP7A	20/10	4	21/10	Annigeri	25/11
	BP7B	20/10	4	21/10	Annigeri	25/11
	BP6C	29/10	4	31/10	Annigeri	25/11
Gw fld.	305	28/10	6	-	K 850	?
	306	27/10	6	-	K 850	?
	307	28/10	6	-	K 850	?

Soil analyses for these sites are given in Table 3.4.

Results are not reported for Hisar as the experiments were either not planted as planned or discarded due to uneven growth caused by variable soil moisture.

Results and Discussion

In the Vertisol fields tested at ICRISAT Center, no hint of response to rhizobial inoculation, N fertilizer application or P fertilizer application could be found, even though growth and yield was good (Table 9.3.1). Thus these factors do not appear to be limiting chickpea in this situation, which is understandable in terms of the history and consequent high *Rhizobium*, avail. N and avail. P levels of these fields (Table 3.4).

At Gwalior also no significant treatment effects could be detected, indicating sufficiency of P and N_2 fixation at this location (Table 9.3.2). However, growth and yield in Fields 305 and 307 were very poor, indicating limitations by other factors (probably water).

Table 9.3.1. Data of mini-NP trials conducted with Annigeri in Vertisol fields at ICRISAT Center, postrainy season 1986/87.

Treatment	Days to flower	Days to maturity	Total dry matter(g/m^2)	Grain yield (g/m^2)	Harvest index(%)
			Parameter		
			BP6A		
1 (+P)	42	95	546.8	282.6	51.7
2 (+P+Rh)	42	96	533.2	279.7	52.5
3 (+P+Rh+N)	41	95	579.3	287.5	49.7
4 (+Rh)	41	94	492.4	254.6	51.7
Signif.	NS	NS	NS	NS	NS
SE	±0.52	±0.76	±21.32	±12.00	± 0.97
			BP7A		
1 (+P)	39	88	438.7	266.7	60.8
2 (+P+Rh)	41	86	425.3	261.9	61.4
3 (+Rh)	40	87	436.0	266.9	61.2
4 (+Rh)	40	88	454.5	272.1	60.1
Signif.	*	NS	NS	NS	NS
SE	±0.47	±0.50	±12.38	±7.36	±0.51
			BP7B		
1 (+P)	40	88	441.4	261.7	60.0
2 (+P+Rh)	40	86	421.3	223.4	54.4
3 (+Rh)	39	87	435.6	261.2	60.1
4 (+Rh)	39	86	421.5	253.2	60.3
Signif.	*	NS	NS	NS	NS
SE	±0.72	±0.66	±26.50	±10.10	±2.26
			BP8C		
1 (+P)	42	100	562.6	237.3	42.1
(+P+Rh)	43	99	560.1	261.1	46.0
(+Rh)	43	100	560.7	203.5	35.6
(+Rh)	43	99	507.3	229.7	44.5
Signif.	*	NS	NS	NS	NS
SE	±0.25	±0.72	±33.03	±15.90	±2.67

Table 9.3.2. Data of mini-NP trials conducted with K 850 in Inceptisol fields at ICRISAT Cooperative Subcenter, Gwalior, 1986/87.

Treatments	Days to 50% flowering	Days to maturity	Shoot dry wt. (g m^2)	Grain yield (g m^{-2})	Harvest Index(%)	Pod no. m^{-2}	Seed no. pod^{-1}	100 seed wt. (g)
				Field 305				
1 (+P)	77	121	202	71	30.0	320	1.07	22.2
2 (+P+Rh)	76	121	204	66	25.5	275	1.13	22.8
3 (+P+Rh+N)	78	125	171	49	24.7	216	1.13	22.5
4 (+Rh)	74	125	223	61	26.7	275	1.03	22.3
Signif.	NS	***	NS	NS	NS	NS	NS	NS
SE	±1.8	±0.3	±34.8	±16.9	±3.75	±69.8	±0.050	±1.30
				Field 306				
1 (+P)	81	124	375	193	54.5	759	1.40	25.7
2 (+P+Rh)	85	125	357	162	46.3	643	1.94	25.3
3 (+P+Rh+N)	88	127	455	214	47.1	826	1.77	25.8
4 (+Rh)	83	125	393	201	51.4	757	1.43	26.2
Signif.	NS	NS	NS	NS	NS	NS	NS	NS
SE	±2.2	±0.9	±40.5	±21.4	±3.11	±84.6	±0.393	±0.51
				Field 307				
1 (+P)	89	122	49	5	12.3	11	1.17	38.0
2 (+P+Rh)	88	121	79	23	21.7	78	1.25	33.4
3 (+P+Rh+N)	90	122	87	15	12.4	48	1.28	28.2
4 (+Rh)	89	122	99	15	15.5	45	1.26	35.2
Signif.	NS	NS	NS	NS	NS	NS	NS	NS
SE	±2.3	±0.5	±12.7	±18.9	±5.07	±20.7	±0.123	±5.58

9.4 PA 86/7 Effect of solarization on growth and yield of pigeonpea and chickpea in saline areas at Hisar (CJ, YSC, NPS)

Introduction

During his consultancy at ICRISAT in September/October 1985, Dr J. Katan mentioned that solarization had ameliorated the effects of salinity on plant growth in a preliminary study in Egypt. For example, with solarization there may be less movement of salt to surface soil layers during hot, dry periods. Due to the salinity problems facing chickpea and pigeonpea, particularly at Hisar, we considered this phenomenon worth at least preliminary investigation. Thus we imposed treatments with and without solarization on moderately saline areas at ICRISAT Sub-center, HAU, Hisar.

Materials and Methods

Treatments of solarization and no solarization were applied for 6 weeks from 29 April 1986, on 3 replications on field No. 8 and 3 replications on field No. 18 at HAU Farm, Hisar. Plot size was 6 x 5 m. Chickpea cultivar ICCV 17 was sown in rows 37.5 cm apart following irrigation on 11 Nov. 1986. 100 kg ha^{-1} SSP was broadcast and mixed in the surface two days later. Thinning to a spacing of 37.5 x 10 cm was done on 30 Nov. Weedings were done on 10 Dec 30 Dec and mid-Jan 1987. Two sprays of monocrotophos were applied after flowering. Plant height was recorded at about 15 day intervals from 10 Dec. Harvesting of surviving plots was done on 28 April 1987.

Results and Discussion

There were some positive effects of solarization on plant height at earlier growth stages but from 100 DAS several plots were badly affected by salinity and had to be abandoned (Table 9.4.1). At 121 and 136 DAS plant height appeared better in nonsolarized plots but this was confounded by the uneveness caused by salinity.

By final harvest, all plots in field 18 and the nonsolarized plot in Rep 1 of field 8 were abandoned, and final harvest data refer only to the remaining plots (Table 9.4.2). Final TDM and grain yield was higher in nonsolarized plots probably because of the better plant stands here (Table 9.4.2). 100 seed mass seemed higher with solarization.

Although initial plant height data indicated a positive effect of solarization, the natural uneven nature of the salinity precluded any conclusions on effect of solarization on salinity effects at later growth stages and at harvest. It is suggested that any effects of solarization on salinity, if they indeed exist, would only be demonstrable in fields of much more even spatial distribution of salinity than recurs at HAU Farm, Hisar.

Table 9.4.1. Effect of solarization on plant height (cm) of chickpea cv ICCV 7 at various stages of growth at Hisar, 1986/87.

Treatment	Plant height at (days after sowing)							
	29	44	60	75	91	106	121	136
Nonsolarized	6.0	9.7	12.3	16.7	23.6	32.6	45.3	49.5
Solarized	6.8	10.6	12.7	18.9	24.2	30.7	34.8	39.9
SEm	±0.24*	±0.22**	±0.21NS	±0.19***	±0.75NS	±1.80NS	±0.96***	±0.89***

NS Difference between means not significant
* Difference between means significant at 0.05 level
** Difference between means significant at 0.01 level
*** Difference between means significant at 0.001 level

Table 9.4.2. Effect of solarization on plant stand, phenology, total dry matter (TDM), grain yield, harvest index (HI) and yield components of chickpea cv ICCV 17 at Hisar, 1986/87.

Treatment	Initial plant stand per plot	Final plant stand per plot	Days to 50% flowering	Days to maturity	TDM at flowering (g $plant^{-1}$)	Final TDM (kg ha^{-1})	Grain yield (kg ha^{-1})	HI (%)	Plants m^{-2}	Pod no m^{-2}	100 seed mass (g)
Nonsolarized	628	227	90.0	148.3	12.2	2530	743	30.5	4.04	18.9	14.4
Solarized	618	187	92.0	155.3	19.7	809	220	26.6	1.89	12.9	18.5
SEm	106.8NS	125.3NS	0.00NS	0.58NS	1.44NS	71.4*	9.5*	1.99NS	0.283NS	1.56NS	0.058