SEED TRAITS IN RELATION TO PLANT STAND ESTABLISHMENT IN CHICKPEA (*Cicer arietinum* L.)

BY

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CERTIFICATE

Miss **B. Padma Sri** has satisfactorily prosecuted the course of research and that the thesis entitled **"SEED TRAITS IN RELATION TO PLANT STAND ESTABLISHMENT IN CHICKPEA (*Cicer arietinum* L.)** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any university.

Date: 10.11.98
Place: Hyderabad.

(Dr. B. GOPAL SINGH)
MAJOR ADVISER

CERTIFICATE

This is to certify that the thesis entitled **"SEED TRAITS IN RELATION TO PLANT STAND ESTABLISHMENT IN CHICKPEA (*Cicer arietinum* L.)"** submitted in partial fulfilment of the requirements for the award of degree of **"MASTER OF SCIENCE IN AGRICULTURE"** of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by Miss. **B. PADMA SRI** under my guidance and supervision . The subject of the thesis has been approved by the Student Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. Published part has been fully acknowledged. All assistance and help received during the course of the study has been duly acknowledged by the author of the thesis.

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DECLARATION

I, **B. PADMA SRI** here by declare that the thesis entitled **"SEED TRAITS IN RELATION TO PLANT STAND ESTABLISHMENT IN CHICKPEA (*Cicer arietinum* L.)"** submitted to Acharya N.G. Ranga Agricultural University for the award of the Degree of **MASTER OF SCIENCE IN AGRICULTURE** is a result of original research work done by me. It is further declared that the thesis or any part thereof has not been published earlier in any manner.

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Date: 10.11.98

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LIST OF SYMBOLS AND ABBREVIATIONS

ABA	: Abscisic acid
AICP	: All India Co- ordinated Project
A.P	: Andhra Pradesh
BD	: Bulk Density
cc	: cubic centimeter
CEC	: Cation exchange capacity
CGR	: Crop growth rate
cm	: Centimeter
cv.	: cultivar
^{o} C	: Degree centigrade
DAS	: Days after sowing
E	: East
et al.	: and co-workers
FAO	: Food and Agricultural Organisation
h	: hour
HI	: Harvest Index
ICRISAT	: International Crops Research Institute for the Semi- Arid Tropics
ISTA	: International Seed Testing Association
Kg ha^{-1}	: Kilogram per hectare
LAI	: Leaf area index
LSD	: Least significant difference
m	: meter
me	: milli equivalents
mg	: milligram
mha	: Million hectare
ml	: millilitre
mm	: millimetre
m mho	: milli mho
M Pa	: Maga pascal

mt	: Metric tonnes
N	: North
NAA	: Naphthalene acetic acid
NS	: Non significant
%	: percentage/per cent
PEG	: Poly ethylene glycol
RH	: Relative humidity
SAT	: Semi-Arid Tropics
S.Em	: Standard error of mean
TSS	: Total soluble sugars
µm	: micro moles
WANA	: West Asia and North Africa
Wk	: week

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ABSTRACT

Seed traits related to plant stand establishment were studied in chickpea during Rabi, 1997 at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad and on two farmers fields located at Yelimella village, Rangareddy Dist., A.P.

Ten plots (1m x 1m) were selected randomly in both the farmers fields. In farmer-1 field half of the plots were irrigated and no irrigation was applied in farmer-2 field because it rained seven days after sowing. Soil moisture was determined at the time of sowing and after irrigation/rainfall in order to relate differences in plant stands with soil moisture content in the seed bed.

At ICRISAT center, four genotypes, which differed in seed size, were studied. Two were local cultivars, collected from the two farmers (farmer 1, farmer 2) and the other two varieties (Annigeri, ICCV2) were taken from ICRISAT. Crop was sown on three different dates to create differences in soil moisture at the time of sowing.

In farmers' fields plant stands were very poor ranging from 4-17 plants/m^2. Reasons for poor plant stand in farmer-1 field was suboptimum seed rate, where as in farmer-2 field, it was inadequate soil moisture and poor seed soil contact due to broad cast method of sowing. Yields were also low in the experiments on both the farmers' fields.

At ICRISAT center, perfect plant stands were established when soil moisture was adequate as observed in sow-I and sow-II (20% to 28%). However, the plant stand was reduced drastically when the soil moisture was suboptimum (18-19%) in the seed bed, as observed in sow-III . Genotypic differences in plant stand and seed yield were not significant in the field experiments conducted at ICRISAT center.

In the glass house experiment, however, where the soil moisture was below the critical required for germination, plant stand was severely reduced due to soil moisture stress (20% and 22%, W/W). Also, genotypes differed in their ability to germinate and emerge from the soil. Genotype farmer 2 was significantly superior to the other genotypes.

The two genotypes collected from farmers (perhaps land races) were smaller in seed size compared to Annigeri and ICCV2. Farmer 2 genotype had also more surface to volume ratio (which was negatively closely correlated with seed size) , which might have facilitated a rapid imbibition of soil moisture, and consequently reaching the hydration state faster. It suggests that smaller seeds, with more surface to volume ratio, can emerge better under sub optimum seed bed moisture contents.

We conclude that small seed size can be used as an indirect measure to select in the germplasm accessions which will have a large surface/volume ratio. These can be evaluated in field experiment to verify the inference drawn that small seeds i.e., with a larger surface/volume ratio will be able to germinate better from suboptimum seed bed moisture or drying out field after the cessation of monsoon rains.

INTRODUCTION

CHAPTER I

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an important cool season food legume crop, which is grown in the important cropping systems of the semi-arid tropics (SAT) of South Asia and West Asia and North Africa (WANA) region. In the Indian subcontinent two types of chickpea are distinguished -- the desi type and the kabuli type. This distinction is made primarily on two considerations, one the seed colour and the second on seed size. Desi type are small and dark in colour, while kabuli types are large and salmon white to creamy in colour (Vander Maesen, 1987).

In South Asia, chickpea is grown mostly as a rain-fed, winter season (*Rabi*) crop. It is usually sown after the cessation of monsoon rains, and frequently subjected to terminal drought and heat stress (Saxena, 1987a). India is the major chickpea growing country in the world with an area of 8 mha and production of 6 mt (FAO,1996). It is an important supplement to cereal food (rice, wheat, sorghum, Bajra) and also an important source of protein, particularly in the vegetarian diets. Chickpea also plays an important role in increasing the productivity and in maintaining the sustainability of the farming systems.

An important step in successful crop production and realising the maximum of the available genetic yield potential is the establishment of

required and uniform plant stands. One of the important considerations in obtaining desired plant stand is the use of good quality seeds which will ensure germination and emergence of nearly all the quantity of the seeds sown (Sivaprasad and Sharma, 1987). Plant stands of chickpea are often poor on farmer's fields in the semi-arid tropical parts of India, where it is grown as a rainfed crop on moisture stored in the soil profile from the previous rainy season. Poor plant stand is a major constraint in realisation of available genetic yield potential in the major areas of chickpea cultivation (Saxena, 1987a).

In Andhra Pradesh the area under chickpea cultivation has increased consistently from 0.077 mha in 1980/81 to 0.134 mha in 1994/95. During the same period the area decreased from 3.01 mha to 1.41 mha in traditional chickpea growing areas such as Punjab, Haryana and UP. Prospects of further increasing the area under chickpea in Andhra Pradesh, are good, provided the crop is made to establish successfully in production systems following rice.

Research on establishment of plant stand has not received adequate attention. A number of factors affect plant stands. Some of the important factors among them are: genetic, agronomic management, diseases, insect pests, and previous cropping history, which affects the quality of seeds, produced. Quality of seeds is also affected by the conditions during storage, which in turn affects plant stands. There are not

many studies, which relate quality parameters of seed with stand establishment in farmer's field and its effect on seed yield. The present research attempts to fill this gap in the knowledge by improving our understanding of the basis for improving plant stands in on-farm conditions. Therefore, the present study was aimed at the following objectives to

- determine the quality and quantity of seed used by farmers for cultivation of chickpea in Telangana area of A.P.
- study factors related to poor plant stand establishment in on-farm and on experimental station.
- investigate physical and biochemical quality parameters of seeds and their effect on seed germination and seedling emergence.
- study the effects of seed quality on water uptake.
- establish causal relationship between quality traits, plant stand and yield.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

In rainfed cropping systems establishment of proper plant stand of a crop is very important because soil moisture at the time of sowing is often not adequate to ensure proper and uniform germination and emergence of all the seeds sown. This is of particular importance in postrainy (*Rabi*) season crops in India which are planted after the cessation of rains. With progressive delay in planting after the cessation of rains, plant stands ~~are~~ get increasingly poor and un-uniform (patchy).

In South Asia, including India, chickpea is sown when the air temperatures commence to decline (29.5/19.8° C), beginning in late October. Thus selection of an appropriate date of planting, which will be specific for a region, is one of the most crucial factors in achieving optimum plant stands. In cropping systems in which chickpea is planted on lands kept fallow in the preceding season, agronomic management practices to conserve moisture in the soil profile are adopted for ensuring proper plant stand establishment and the subsequent good crop growth. Moisture conservation to ensure adequate availability of soil moisture to meet the crop water requirement at critical crop growth stages and development are crucial for realisation of full yield potential of chickpea.

Plant stands can also be improved by sowing seeds at soil depths where moisture is adequate for seed germination and seedling emergence. The other option is to select genotypes of high quality that are able to germinate and emerge at sub optimal seedbed moisture content (Saxena *et al.*, 1983). For obtaining maximum chickpea yield it has been found through a large number of field experiments that a population of 33 plants m^{-2} is optimum in a wide range of environments in India (Saxena, 1980). Thus seed rates, adjusted for seed size, to achieve the desired plant stand, is one of the most important agronomic management factor.

Once these basic requirements are met, the other factors such as, use of good quality (viable, vigorous) seeds; and control of soil-borne diseases and insect pests becomes other important factor in further improvement of proper stand establishment.

2.1 Factors affecting plant stand establishment

Climatic factors play an important role in the induction of seeds to germinate. These effects of climate are primarily through adequate availability of soil moisture (a result of rainfall), distribution of rainfall and optimum temperatures for the germination of seeds and initial growth facilitating emergence of seedlings. These climatic factors also have a pronounced effect on changes in the levels of phyto-hormones such as the effect of temperature (Khan and Tao, 1978).

2.1.1 Water stress or drought

Drought is one of the single most important among various factors that inhibits expression of potential productivity of most of the crop plants including cool season food legumes such as chickpea, fababean, lentil, pea across very diverse agro-climatic regions (Smith and Harris, 1981; Virmani *et al.*, 1980).

Moisture content at soil depth, at which sowing is often done, is generally insufficient for seed germination, seedling emergence and crop establishment. Poor and irregular plant stand is often the major cause for the large yield gap observed between farmer's fields and experimental stations in chickpea (Saxena, 1987b).

The cool season food legumes may experience two types of drought stress, depending on the season of cultivation (Saxena *et al.*, 1993):

- Intermittent drought stress caused by breaks in winter rainfall in WANA and
- Terminal drought stress resulting from receding soil moisture in winter planted chickpea in the SAT and spring chickpea in WANA.

Saxena *et al.* (1993) also reported that autumn or winter sown crops in mediterranean environments are likely to experience intermittent

drought during vegetative stages of growth and terminal drought in the reproductive period. Further the spring sown crops in the mediterranean environments and winter sown crops in the semi-arid tropics, which are grown on residual soil moisture, experience progressively increasing terminal drought and heat stress.

The severity of terminal drought stress depends not only on moisture input by precipitation and its distribution, but also on the capacity of the soil to store moisture and the evaporative demand of the atmosphere (Saxena, 1987a).

There are two major effects of drought on agricultural productivity, one is failure to establish the desired plant stand, and the other is reduction in crop growth and yield due to sub optimal soil moisture availability for crop growth (Saxena *et al.*, 1993).

From the above findings it is clear that the harmful effects of unfavourable weather conditions are quite critical during germination and early seedling development stage which can not be completely compensated by improvement of crop growth conditions at later stages of vegetative growth. Successful germination of seeds under a wide range of soil moisture and temperature conditions, therefore, is very important for early plant stand establishment.

Effects of water stress, induced by PEG, indicated that water uptake, percentage seed germination, germination relative index, seedling growth and seedling vigour declined with the increase in water stress in large (macrosperma) as well as small (microsperma) seeds of chickpea (Singh and Afria, 1985).

Gupta *et al.* (1991) studied seed germination of a drought resistant and a susceptible variety in petridishes at a range of water potentials (from control (0) to -0.49 M Pa) induced by different concentrations of polyethylene glycol (PEG). They found that the drought resistant chickpea variety (C 214) had a higher per cent of germination compared to the susceptible variety (PBG 9) at lower water potentials.

Rainfall after seed germination contributes not only to adequate soil moisture but also is important in establishing uniform and vigorous plant stands in WANA (Northern Syria). Thus matching planting in a region with time of good probability of small amounts of winter rainfall would be beneficial to improve plant stands substantially when crops are sown early (Keatinge and Cooper, 1983).

From literature reviewed it is apparent that in vertisols around 23-24% soil moisture (w/w) is optimum for seed germination and seedling

emergence. In these types of soil no seed germination was observed at 19% moisture. Genotypic differences in seedling emergence were apparent at 21% and 22% soil moisture content. In the above studies a few genotypes, such as G-130 Rabat and Annigeri were found to germinate and emerge better compared to genotypes L-550 and K-4-1 from limiting soil moisture content (Saxena *et al.*, 1983).

Successful establishment of seedlings during periodic dry spells requires a primary root capable of rapid downward elongation because of frequent and severe drying of the seed bed, which may restrict development of lateral roots (Jordan and Miller, 1980). Rapid root development and growth would facilitate successful establishment of seedlings after sowing (Asay and Johnson, 1983).

Conservation of moisture in root profile by incorporation of agrochemicals like Jalshakti , a non toxic and bio degradable material, has been shown to improve and stabilise yields of chickpea during *Rabi* season. Soil incorporation of Jalshakti improved soil aeration and also increased the soil moisture use efficiency when water was limiting. Further the seed coating with Jalshakti increased the seed yield compared to control (Joseph and Varma, 1994).

2.1.2 Temperature

Temperature, an index of sensible heat of atmosphere, is an important parameter which influences the growth and development of plants (Singh *et al.*, 1994). It influences the rate of emergence of seedlings in the seed bed and determines the final plant stand in legumes (Bewley and Black, 1982). However, germination of most legumes is not adversely affected in the temperature range between 10° C and 25° C (Brar *et al.*, 1991).

Smith *et al.* (1987) showed that in chickpea, the highest seed germination index was observed at 22° C in cv.garnet in laboratory experiments. Further, the small seeded type (100 seed wt. of 12.5g) showed a higher germination index than the large seed types (100 seed wt. of 17.0g) at temperature of 19.5 to 28° C.

Since temperature, strongly influences the germination in chickpea, the date of sowing, therefore, should be so selected that the diurnal thermal regime at a given location/region is optimum for germination and seedling growth (Singh *et al.*, 1994).

In cool regions, such as in northern parts of India delay in sowing of chickpea due to delay in harvest of rainy season crops, like rice

delays seedling emergence and decreases radicle length and vigour index. This decrease in growth parameters is related to the decline in temperature which occurs with progressive delay in sowing (Dixit *et al.*,1992). For example, the day/night temperatures at the time of sowing in October at ICRISAT Center, Patancheru, A.P. are 29.5/19.8° C but if the sowing is delayed to December the diurnal temperatures will be 28.1/18.1° C (Saxena, 1984).

2.1.3 Growth regulators or Phyto-hormones

Plant-hormones are known to regulate germination of seeds (Jacobson *et al.*, 1979; Ilan and Gepstein, 1981). Changes in endogenous levels of growth promoters and inhibitors, seems to be a consequence of seed development (Davis, 1987). Production of these endogenous chemicals has been regulated through application of chemicals used as a tool for managing crops and increasing their potential to maximise crop yield (Singh and Jain, 1982; Setia *et al.*, 1993).

Among the different phyto-hormones, cytokinins in angiosperms (Dimalla and Vanstaden, 1977; Julin-Tegelman and Pinfield, 1982) as well as in gymnosperms (Taylor and Wareing, 1979) are known to play an important role in the mobilisation of seed reserves during germination. Ethylene is shown to increase germination in many crops. In

chickpea, seed' embryonic axis of the seed seems to be the main site for the production of ethylene in significant amounts (Sanchez-Calle and Matilla, 1989; Gallardo *et al.*, 1991). In some cases, exogenous supply of cytokinins could mimick the presence of embryonic axis in regulating the production of ethylene (Gepstein and Ilan, 1980).

Germination of seeds in chickpea is also delayed by supra optimal temperatures (>30° C) or through application of abscisic acid (ABA) at 25 *um* concentration. Thus there are similarities between the effects of high temperature and ABA on germination and growth of the embryonic axis. Both these factors, high temperature and ABA, decrease the growth which in turn have effects on ionic exchange, water uptake and cell elongation, (Hernandeze-Nistal *et al.*,1983; Rodrigueze *et al.*, 1983). These effects are counteracted by thiourea and fusicoccin (Aldasoro *et al.*, 1981). Since chickpea seeds have an optimal temperature of around 25° C for maximum germination, a temperature of 30° C causes a delay of approximately 24 hours in germination and 24-36 hours in appearance of cytokinins in cotyledons. The transport of cytokinin from the axis to the cotyledon also undergoes a similar delay and at 25° C no passage of cytokinins occur from cotyledons to the embryonic axis (Revilla *et al.*, 1988).

Cytohexylamine and methylglioxalbis, which are inhibitors of polyamine synthesis, when added to the medium used for germinating seed, increased the ethylene production and thereby the germination in chickpea

(Munoz de-Rueda *et al.*, 1993). This effect was observed both at 25° C (control treatment –optimum temperature for germination) and at 30° C (thermo-inhibiting temperature for germination). The stimulation was inhibited at higher temperatures (35° C) because of the lack of production of ethylene and accumulation of putrescine and spermine both in free and bound forms (Munoz de Rueda *et al.*, 1993).

2.1.4 Soil physical conditions

There are other soil conditions, which could change after sowing of the seeds, apart from the preparation of seed bed at sowing time, which could affect adversely seedling emergence. Events that cause changes in soil structure after sowing seeds, such as the formation of soil crusts (Heydecker, 1956) is one of such adverse conditions. Rainfall after sowing is one such factor, which could result in crust information. The magnitude of compaction varies with the size of rain drop and the intensity of rainfall. The mean time of emergence of seedling from the soil subjected to larger rain drops is longer (Sivaprasad and Sharma,1987). In some small seeded crops e.g. pearl millet, complete crop failure has been observed because of surface soil compaction, and crust information (Kumar *et al.*, 1992).

2.1.5 Sowing date

In rainfed cropping system soil moisture declines with time after cessation of rainfall and the rate of depletion of soil moisture because of evaporative loss. There are field studies in which effects of serial sowing dates on soil moisture content in the seedling zone, and the effect of declining soil moisture content on seed germination, have been studied on Vertisol (Black Cotton Soils). In one of such studies the percentage of seedling emergence did not differ significantly in the first two sowings (28th Jan and 4th Feb)when the soil moisture at 0-5 cm soil depth ranged between 23 to 26%. But the percentage germination fell significantly in the third sowing (9th Feb), when the soil moisture was around 20% (w/w) which appears to be the critical soil moisture content for discriminating genotypic differences in seed germination in that type of soil (Saxena *et al.*, 1983).

In spring planted chickpea in the Palouse region of northern Idaho and eastern Washington, USA, the effect of planting date showed that the values for germination and radicle elongation were maximum at 20° C in laboratory. But under field conditions late planting in April gave the highest seed yields. However, there was a delay in seedling emergence. Among the genotypes studied desi lines showed a higher percent of emergence than the kabuli types. A comparison of cultivars for dry matter accumulation further indicated that it was rapid in kabuli lines with larger seeds compared to desi types (Auld *et al.*, 1988).

Date of planting has proved to be the single most important factor affecting the yield of chickpea. Extensive work under the All India Co-ordinated Project (AICP) revealed that dates of planting, ranging between mid October to mid November, are most appropriate for sowing chickpea crop. Any deviation in sowing time, earlier or later than the range specified results in significant yield reduction (Kaul and Sekhon, 1976; Sharma, 1978).

2.1.6 Seed size

2.1.6.1 Effect on germination

Seed size reflects the amount of substrate stored for seedling growth in chickpea. Small and shrivelled seed, which have relatively small quantities of storage reserves, produce less vigorous seedlings compared to vigorous plants produced from bold and plumpy seed (Bremmer *et al.*, 1963, Naryanan *et al.*, 1981; Saxena *et al.*, 1981).

Large-seeded varieties of chickpea produce larger and more vigorous seedlings, which will have an advantage in stand establishment under adverse conditions. A positive correlation was observed between seed weight and the leaf area and dry weight of chickpea seedlings (Narayanan *et al.*, 1981). In chickpea, larger seedlings produced from large seeded varieties may emerge better after deep sowing, which is often necessary when the crop is sown in seed-beds which are drying out (Vander maesen, 1972).

In other crops like lentil, (*Lens culinaris*) seed size was positively correlated with seed impermeability (r=0.75) and germination (r=0.77). A strong, negative and highly significant correlation (r=-0.95) was observed between seed impermeability and germination. These traits confer better seed germination in larger than the smaller seeds (Shahi *et al.*, 1986).

In cereals, especially in wheat, seed size did not affect the germination in laboratory conditions, but seedlings from large seed emerged more rapidly in the field. Larger seed produced taller, heavier and more tillers than smaller seed. However, Differences in seed size did not affect the grain yield (Chastain *et al.*, 1995; Ragasits and Lonhardne, 1992). In case of sorghum also the seed size did not affect the germination (Singh, 1987).

In cereal crops like soft red winter wheat, germination percent was not affected by seed size. Experiment conducted in growth chamber using solutions of mannitol indicated that germination percent was reduced by low water potential, but was not affected by seed size. Dry weight accumulation in the seedlings from large seeds (35 mg $seed^{-1}$) was larger than from medium (26 mg $seed^{-1}$) and small size seeds (17 mg $seed^{-1}$). The ability of larger seeds to produce larger seedlings than smaller seeds was pronounced in drought than under well-watered conditions (Mian and Nafziger, 1994).

In oil seed crops like groundnut, effect of seed size on germination were studied at Kasetsart University, Bangkok with cv. Tainan9. Higher seed weight and seedling dry weights were obtained from large seeds than from small seeds. In laboratory studies no significant effect of seed size was observed on field emergence. However, small seeds germinated faster than the larger seeds (Duangpatra and Tongteera, 1986). In other studies large seeds showed higher germination percent in laboratory and also higher field emergence (Lee *et al.*, 1985).

2.1.6.2 Effect on seed vigour

Large seeds (>20g/100seeds) showed a higher range of variation in total soluble sugar content, higher electrical conductivity of seed leachates and mean seedling dry weight compared to small seeded cultivars. However, the small seeded varieties recorded more seedling vigour due to less electrical conductivity (Raje and Khare,1996).

An experiment was conducted at Hissar, India with four classes of seed masses, Kabuli bold, Kabuli small, Desi bold and Desi small to study the effect of variation in seed mass on seedling vigour and other quality attributes. From this studies it was obvious that root length and protein content were high in Kabuli types than in the Desi types. Seed volume, hydration capacity, swelling capacity and electrical conductivity was higher in

bold seeded varieties than in the small seeded ones in both Kabuli as well as Desi groups (Waldia *et al.*, 1991).

The effects of seed size and seed density on germination and seedling vigour in Soybean was evaluated by standard germination test, single seed leachate conductivity and bulk conductivity test by Hoy and Gamble (1985). The largest and low-density seeds performed poorly in the standard germination test. Single seed leachate conductivity levels were highest for large seeds and low for the low-density small seeds. Bulk conductivity tests showed high levels of leakage in large seeds indicating poor germinability and seedling vigour.

In fibre crops like cotton, seed size and density influenced germination and seed vigour index. Larger seeds gave higher seedling vigour index and germination compared to medium and small seeds (Biag, 1986).

2.1.6.3 Effect on yield

Experiments at ICRISAT, Hyderabad, revealed that primary and secondary branches contributed most of the seed yield in chickpea. Also the pod number per unit area was related to seed size and seed weight. The bold seeded cultivars generally produced relatively few pods. The low pod

number in some cultivars was adequately compensated by the hundred seed weight thus producing the same yield as small seeded varieties, which produce large number of pods (Saxena and Sheldrake, 1976).

In chickpea, large seeds produce young plants which are larger in size than those produced from small seeds. These differences continue to remain significant in the first six weeks after sowing but become non significant by the time of harvest and therefore do not reflect in any yield increase. This is presumably because the plants are grown at optimal spacings in normal agronomic conditions in which plant-to-plant competition for space, light, nutrients and water limits the growth of the individual plants as their size increases. Therefore, grading of seeds does not have any practical applied agronomic significance under normal Indian conditions (Saxena *et al.*, 1981). However at Ankara (Turkey), large seeded types produced on an average 31.4% more economic yields than the small seeded types (Eser et al., 1991).

Bhor *et al.* (1988) explained that in chickpea crop, seed size had no significant effect on final plant count, number of pods and grains per plant, grain yield per plant and per plot, germination percentage, vigour index and moisture content. Based on this data the authors concluded that seed grading has little or no economic value to farmer.

A higher degree of seedling emergence, earliness in days to 50% flowering, greater plant height, better final plant stand, high biological and grain yields and harvest index were obtained from large seeded varieties when compared to small seeded varieties in chickpea at Ankara, Turkey (Eser et al., 1991). Similarly Raje and Khare (1996) reported that small seeded varieties took more number of days to 50% flowering compared to large seeded varieties.

Enrique and Jaun (1992) conducted an experiment on lentil in two environments with contrasting differences in productivity in the IX Region, Chile. Seed grading did not affect germination but field emergence was significantly low in both environments with smaller seed size. In more productive or favourable environments seed grading did not affect the seed yield whereas in an environment that inhibited crop growth, seed yield was lower when smaller seeds were used (7mm-5mm seed diameter).

Thus there seems to be a large and contrasting difference in the relationship between seed size and plant stand establishment and growth and yield parameters depending upon the agro-ecological conditions under which crop has been planted.

It is interesting to note from the published literature, in general, that the effects of seed size on germination and plant stand establishment

are more apparent and significant in legumes than in cereals. However, the larger seeds tend to establish better crop stand.

2.1.7 Seed storage and quality

In agriculture it is necessary to store seeds for one or more season to use as seed for next or subsequent season crop. The stored seeds thus need to retain vigour and viability during the period of storage. Chickpea cotyledons are rich in carbohydrates and especially in starch which ranges from 48-66%. It has been noticed that kabuli varieties have more starch and sugar content compared to the desi varieties (Lal *et al.*, 1963). Evidence shows that the potential storage life of seed varies between species (Harrington, 1972; Agrawal, 1980) and also with in species (Agrawal, 1977; 1979). Chickpea genotypes reached a maximum germination percentage at 23 months after harvest, which may be an after-ripening effect in chickpea (Smith *et al.*, 1987). These genetic traits are important in improving the seed quality during storage and have lot of applied significance in practical agriculture.

During storage, respiratory losses of sugars occur thereby reducing the availability of substrate for rapid seed germination (Agrawal and Kharlukhi 1985). In these studies it was found that leaching of electrolytes was more from chickpea seeds stored at high temperature (33° C) and high

humidity (80% RH) compared to 20° C temperature and at 30% RH. Leaching of water-soluble sugars was attributed to loss in membrane integrity during storage, an indication of the commencement of seed deterioration. It was also shown that chickpea looses its germinability 15 days after storage at 33° C and at 33% RH but could be prolonged if stored at 20° C and 30% RH% (Agrawal and Kharlukhi, 1985).

Seed quality in terms of metabolite content of the seed is also affected by adverse soil conditions such as degree of salinity and the stage of growth at which crop is affected and growth regulators used. Salinity does not affect sugar content but decreases the starch and protein contents. Foliar application of Naphthalene Acetic Acid (NAA) produces seeds with relatively higher amounts of amino acids in seeds (Dhingra *et al.*, 1995).

Disease and insect pests also affect seed quality during storage, and during germination and plant stand establishment in field. From the literature it is obvious that treating the seed with thiram (up to 0.3%) provides protection to seed from losses in germination even if it is stored under adverse condition i.e. higher RH (Vyas and Nene, 1984).

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1 Site characteristics

The present investigations, both laboratory and field experiments were conducted in the chickpea physiology laboratory of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, A.P. Two experiments were also conducted on the farmer's fields [Farmer-1 Narayana P and Farmer-2 Krishna K] located at a distance of 15 km from ICRISAT in Yelimella village, Rangareddy Dist., A.P., India.

Experiments at ICRISAT Center, Hyderabad (17° 32' N, 78° 16' E, altitude 542 m) were conducted on a Vertisol fields (BP 13). The soil characteristics are given in Table 1. These Vertisols are low in native soil available nitrogen; medium in available phosphorus and high in exchangeable potassium. The pH was around 8.0. No fertilisers were added to the fields, both on experimental station as well as on farmer's fields because earlier experiments at ICRISAT have shown that chickpea does not respond to the application of nitrogen, phosphorus and potassium containing chemical fertilisers on these Vertisols.

The experiment was conducted using four genotypes --two local cultivars obtained from farmers (farmer 1 and farmer 2), and two cultivars (Annigeri and ICCV2) were taken from ICRISAT. The soil on farmer's field was

a clayey loam, while at ICRISAT it was a heavy clay (Vertisol) with clay content >60%, CEC of 40 me/100 g soil, and the soil depth was greater than 2.0 m. The physico-chemical characteristics of the soil and nutrient status at the experimental sites are given in Table 1.

Table1: Physico-chemical properties of experimental site

Particulars	Farmer-1		Farmer-2		ICRISAT	
Soil depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30
Physical characteristics						
pH	7.7	7.8	7.8	7.9	8.1	8.1
Electrical conductivity (m mhos/cm)	0.26	0.21	0.34	0.31	0.25	0.25
Nutrient status						
Organic carbon (Kg ha^{-1})	Low		Low		Low	
Available nitrogen (Kg ha^{-1})	Low		Low		Low	
Available Phosphorus (kg ha^{-1})	20	10	15	15	7.5	12.5
Available potassium (kg ha^{-1})	270	221	194	243	251	246

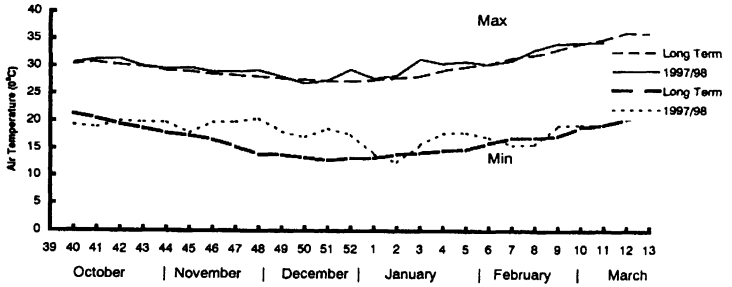
3.2 Climate

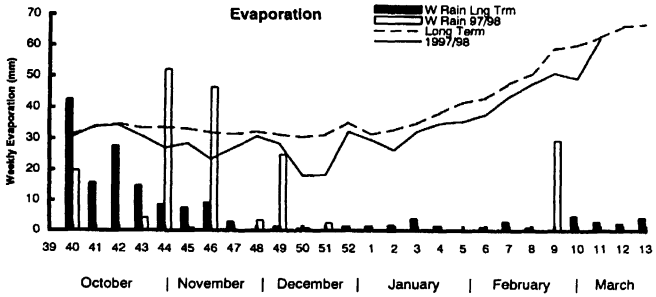
Climatic conditions during the crop growth 1997/98 at ICRISAT were shown in the Fig. 1

3.2.1 Rainfall: In November, 1997 approximately 103.2 mm rainfall was received during the crop season which is very high compared to long-term average. This rainfall affected the date of planting. Since the aim of the experiment was to sow the crop with receding seedbed moisture, third sowing was done in January, 1998, when the moisture content receded to 18-19%. In December 31.7 mm rainfall was received after the sowing of the second crop.

3.2.2 Temperature: Maximum temperature in 1997/98 season was more or less similar to long term average (1974-96). However, the minimum temperature during 1997/98 cropping season was higher than the long-term average temperature and touched to 20^{0}C in November and December compared to 15-16^{0}C of long-term average.

3.2.3 Evaporation: In 1997/98 cropping season evaporative losses were less compared to long term average.





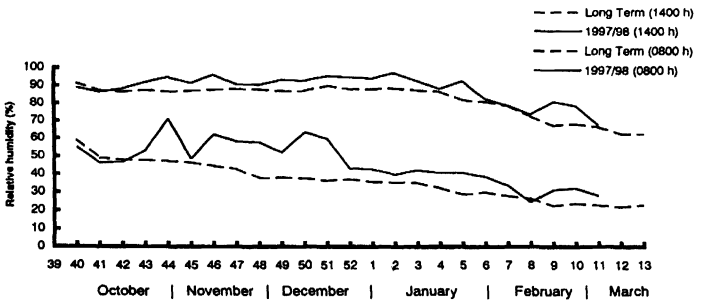


Fig 1. Weather conditions at ICRISAT during 1997/98 season in comparison to long term climatic conditions (1974-1996).

3.3 Methods

3.3.1 Soil sampling

Soil samples from farmers and ICRISAT fields were collected periodically for estimation of soil moisture content to decide the dates of three different sowings to coincide with decreasing levels of soil moisture content. Bulk soil samples were also collected for soil physico-chemical analysis.

3.3.1.1 Soil sampling for chemical analysis

Top surface soil samples (0-15 cm) were collected with the help of a spade. At the very same spot, soil was dug further to a depth of 30 cm to collect another sample from 15-30 cm depth. The two samples were labelled. Soil samples were collected at six different spots covering the whole experimental area in the field and were bulked. The samples were then air dried, powdered, and sieved . Samples were analysed for pH (1:2 soil water extract), electrical conductivity (Jackson , 1967), organic carbon by the Wet digestion method of Walkley and Black (Jackson, 1973), available phosphorus by Olsen's method (Olsen *et al.*, 1954), available potassium by Flame photometer (Jackson, 1967) and available nitrogen by Alkaline permanganate method (Subbaiah and Asija, 1956).

3.3.1.2 Soil moisture determination

Soil samples were collected from 0-5 cm and 5-10 cm depth using a scoop and put in to empty and aluminium tins of known weight. Six sites were sampled covering the whole experimental area in the field. Fresh weight of soil + tin was taken in the field using a battery operated electronic balance (Terraillon, France) to avoid loss of soil moisture from the fresh samples. The soil samples were oven dried at 108°C for two days and weights were recorded using the same balance.

Soil samples were collected from farmer's field at the time of sowing, 10 DAS (before irrigation), and also 2 h after irrigation. At ICRISAT, the experiment was irrigated uniformly with 5 cm irrigation (applied with rose cans) to saturate moisture in the surface layer. Soil samples were collected seven times on different dates spread between the first date (4-11-97) of sowing and the third date (6-1-98) of sowing to monitor the rate of depletion of soil moisture as the field was drying out. Moisture content was calculated using the formula.

$$\text{Percent soil moisture} = \frac{\text{Fresh wt. of soil (g)} - \text{Dry wt. of soil (g)}}{\text{Dry wt. of soil (g)}}$$

Seeds were also collected from the two farmers to conduct field and laboratory experiments at ICRISAT experimental station.

3.3.2 Method of sowing

Sowing was done by Farmer-1, with a bullock drawn implement i.e., Gorru. Farmer-2 did the sowing by broadcast method. At ICRISAT, the sowing was done with a JD 7100 cone planter, to ensure sowing at a uniform soil depth of 7.5 cm. Four rows were planted at a time with forty one seeds in each row of 4 m length to give a potential plant density of 33 plants m^2.

3.3.3 Experimental design and lay out

The details of the experiment, treatments, plot sizes sown, replication and design of experiment are described below.

On-farm experiments

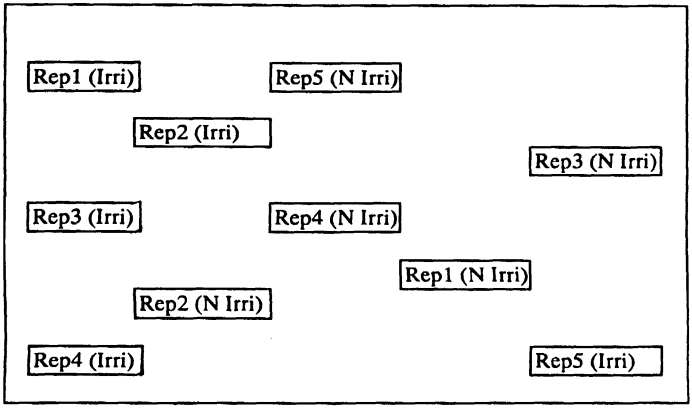
Locations	:	Yelimella village, Ranga Reddy district
Reps	:	Ten plots were selected randomly
Net plot size	:	1m x 1m
Seed rate	:	Farmer-1: 25 Kg ha^{-1}
		Farmer-2: 43 Kg ha^{-1}
Irrigation	:	Only applied in farmer-1 field to half the number of plots (Five) to create irrigated and unirrigated treatments.
		In the field of farmer-2 no irrigation was applied as it rained immediately two days after sowing and before the seedlings emerged.
Sowing date :		Farmer-1: 4-10-97; Farmer-2: 13-10-97

Experimental station trial

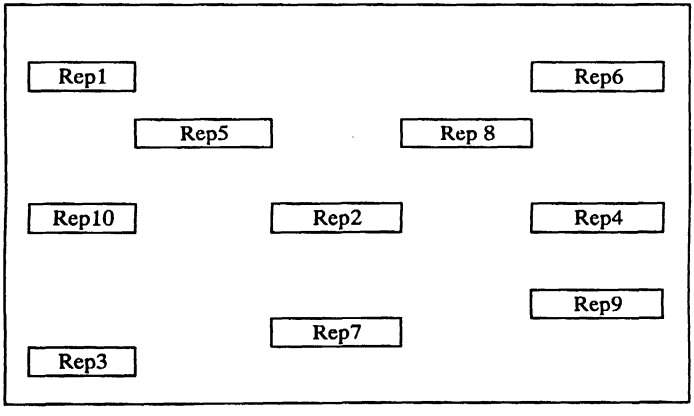
Location	:	ICRISAT Center
Total treatments	:	24 (4 varieties x 3 sowing dates x 2 irrigation levels)
Season	:	Rabi 1997/98
Design	:	Split-split plot design
Main plot	:	Sowing dates: three, 4-11-97, 1-12-97, and 6-1-98.
Sub plot	:	Irrigation levels: Two, Irrigated, non irrigated
Sub-sub plot	:	Genotypes: Four, Three desi genotypes Farmer variety 1 (Farmer1) and Farmer variety 2 (Farmer2) and Annigeri, and ~~ICCV~~2 (~~Kabuli genotype~~). Kabuli genotype i.e., ICCV 2 from ICRISAT
Replications	:	3
Net plot size	:	4m x 1.2 m.
Spacing	:	30 cm x 10 cm.
Seed rate	:	Sub-sub plot consisted of four rows; 41 seeds/row.
Soil type	:	Vertisol
Irrigation	:	Immediately after the sowing half of the plots were irrigated and half of them were left unirrigated.

The lay out of the experiment on the farmer's field is shown in Fig. 2 and at ICRISAT centre in Fig. 3.

FARMER - 1

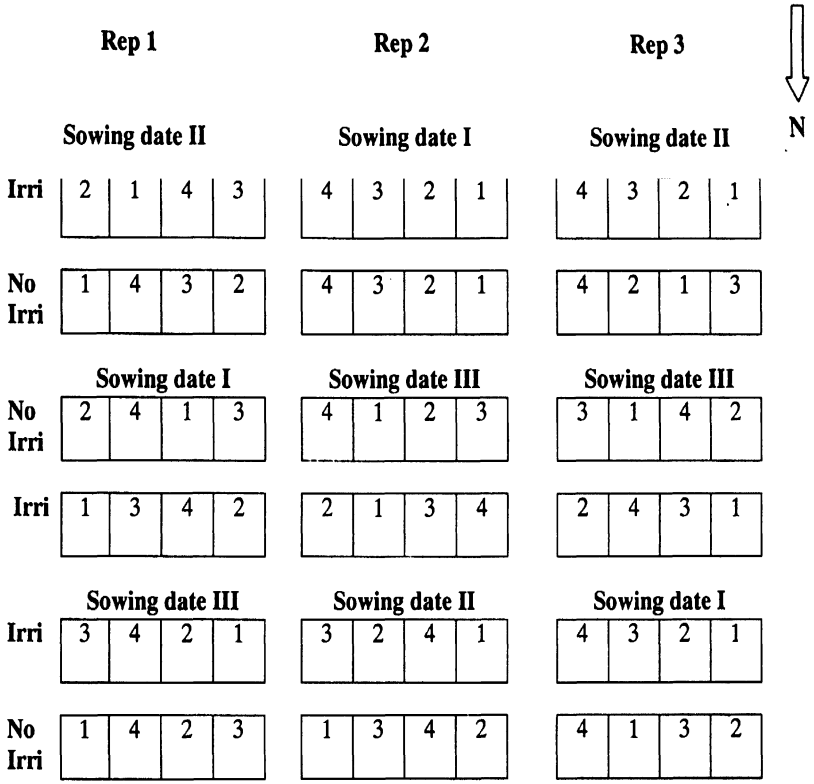


FARMER - 2



Irri = Irrigated
N Irri = Non Irrigated

Fig 2 : Lay out of the experiment on the two farmer's fields



Main plot : Sowing dates (3) I = 4-11-97
II = 1-12-97
III = 6-1-98

Sub plot : Irrigation levels (2) Irri = Irrigated, No Irri = Non Irrigated

Sub-sub plot: Genotypes (4) 1: Farmer 1
2: Farmer 2
3: Annigeri
4: ICCV 2

Replications : 3

Design : Split-split plot

Fig 3: Lay out of the experimental plot at ICRISAT Center, Patancheru

3.4 Observations

3.4.1 Plant counts

In all the three experiments, both on farmer's field and at ICRISAT experimental station, plant stands were recorded on 10th day after sowing (DAS) in all the treatments. In farmer-1 field, plant counts were recorded again ten days after irrigation. Since rainfall occurred (50.4 mm) after sowing by farmer-2 the plots were not irrigated. Plant counts were again recorded in the field of farmer-2, ten days after the rainfall.

3.4.2 Crop growth and yield

3.4.2.1 Growth Analysis

Plants were sampled from 0.5 m^2 area. The samples were taken 85 DAS and 75 DAS from the fields of farmer-1 and farmer-2, respectively. Leaves from one plant were separated to determine leaf area using a leaf area meter (LI-COR Model 3100 Area meter). The plants were separated into component parts stems, and leaves, and kept in separate paper bags. The samples were dried for four days in a force-draft air oven and their dry weights were recorded.

In the experiments at ICRISAT Centre, plants in two rows (0.34 m^2) were sampled from all the plots at 40 and 47 DAS in all the treatments. Leaf area and dry matter were recorded as described earlier.

The basic data on leaf area and dry matter production were used to calculate the various crop growth attributes by the method described by Watson (1952) and Radford (1967).

1. Crop growth rate (CGR) (g m^{-2} wk^{-1}) : $\frac{W_2-W_1}{(t_2-t_1)\ P} \times 7$

Where W_1 and W_2 are the dry weights of plants per square metre at times t_1 and t_2 respectively. P is the land area.

2. Relative Growth Rate (RGR) (g g^{-1} day^{-1}) : $\frac{\log_e W_2 - \log_e W_1}{t_2-t_1}$

Where W_1 and W_2 are plant dry weights at time t_1 and t_2 respectively.

3. Leaf area index (LAI): $\frac{\text{Leaf area}}{\text{Unit land area}}$

4. Harvest index (HI) %: $\frac{\text{Economic yield}}{\text{Biological yield}} \times 100$

3.4.2.2 Other observations

The data on days to 50% flowering and physiological maturity were recorded on whole plot basis.

3.4.2.3 Yield attributes

At harvest, four plants from centre rows and four plants from border rows in all the treatments were sampled for branch wise analysis of the yield and yield components. Number of primary, secondary, tertiary branches/plant, pod number/branch, seed number/pods, 100 seed weight and sub sample yield were recorded. The plants were sun dried and threshed by hand using wooden mallets. Weights were recorded for the sun-dried plants before threshing. Seeds were cleaned (winnowed) and the data on grain yield were recorded for all the treatments.

3.5 Lab Experiments

Water uptake by seeds was studied in all the four genotypes. Seed volume, seed moisture content, germination per cent, and chemical analysis of seeds for protein, carbohydrate and crude lipid content was done at ICRISAT.

3.5.1 Kinetics of water uptake

This experiment was done to study the genotypic differences in uptake of water. For this purpose 100 seeds of uniform size were taken and kept in 100 ml beaker, replicated six times. Initial weight of seeds was recorded. Sufficient quantity of water was added to the beaker to immerse the seeds completely. At every 2 h interval seeds were taken out from water and

bottled to dry the seed surface and seed weights were recorded. The seeds again put back in water in the beaker soon after the weights were taken. Observations were repeated at two hourly intervals for first 16 h and a final observation was taken at 24 h after the experiment was commenced. At the end of the experiment seeds were dried in an oven at 80°C for 24 h and dry weights were recorded. Uptake of water was computed at 2 h interval from the data recorded.

3.5.2 Measurement of seed volume

The volume of seeds was determined by water displacement method. Known quantity of water was taken into a measuring cylinder, the seeds were then placed in the cylinder. The final volume was recorded. The difference in final and initial volume was computed as the volume of 100 seeds.

3.5.3 Seed moisture content

Initial weight of twenty seeds uniform in size of all the four genotypes was recorded. Afterwards, the seeds were kept in paper bags and dried in an oven at 80°C until constant weights were recorded. The moisture content was determined as per ISTA (1993) rules following the formulae given below.

$$\text{Seed moisture content} = \frac{\text{Initial wt. (g) - Oven dry wt. (g)}}{\text{Oven dry wt. (g)}} \times 100$$

3.5.4 Germination percent

Fifty seeds of uniform size of all the genotypes were placed in petriplates lined with whatman No. 42 filter paper. 100-150 ml of water was added to petriplates to soak the seeds thoroughly. All the petriplates were kept in a germinator. After 4 days, the germination counts were taken.

$$\text{Germination \%} = \frac{100}{50} \times \text{No. of seeds germinated}$$

3.5.6 Chemical analysis of seeds

To study the chemical seed constituents which may be related to germination and emergence of seeds of all the four genotypes were analysed for total protein (Industrial method No. 146/71A, 1972 and Singh and Jambunathan, 1980), total soluble sugars (TSS) (Dubois *et al.*, 1956), starch (Southgate, 1976 and Dubois *et al.*, 1956) and oil (Official and tentative methods of AOCS, 1981).

3.5.7 Glass house experiments

An experiment was conducted to compare the four genotypes used in the field studies to find out the effect of genotypic differences in physical seed quality parameters such as, surface to volume ratio, and seed size (seed mass) on seedling emergence at different soil moisture levels (20-22%) under glass house conditions. To conduct this experiment sieved soil with 7.5% moisture content was taken in iron trays of known volume.

Volume of tray (cc) = Length (cm) x Width (cm) x Height (cm)

The volume of the trays is equated to the volume of dry soil filled in the trays. The soil was compacted in the trays to achieve a bulk density of 1.1g cm^{-3}. Then oven dry weight of soil filled in trays was calculated by multiplying B.D with volume of soil. From this the weight of soil (7.5% moisture content) used in this experiment was calculated. Later, the soil was brought up to the target treatment soil moisture content of 20% and 22% by adding water by spraying and mixing it thoroughly. The soil was filled in seed trays and compacted to a bulk density of 1.1g cm^{-3} by using wooden plank. Seeds were sown in rows (made with a wooden row marker) and covered with soil kept aside for this purpose for each treatment trays. After sowing, the soil was compacted as described above. The trays were covered with a polyethylene sheet to avoid evaporation of soil moisture and were kept in green house. The data on emergence were noted on every day.

3.5.8 Measuring the diameter of the seeds

Diameter of the seeds of four genotypes was measured with the help of Vernier caliper (Mitutoyo dialcaliper, Japan). Diameter of each seed was measured in three different directions i.e. two across the seed and one across the beak. At the time of sowing the volume of the seeds was measured

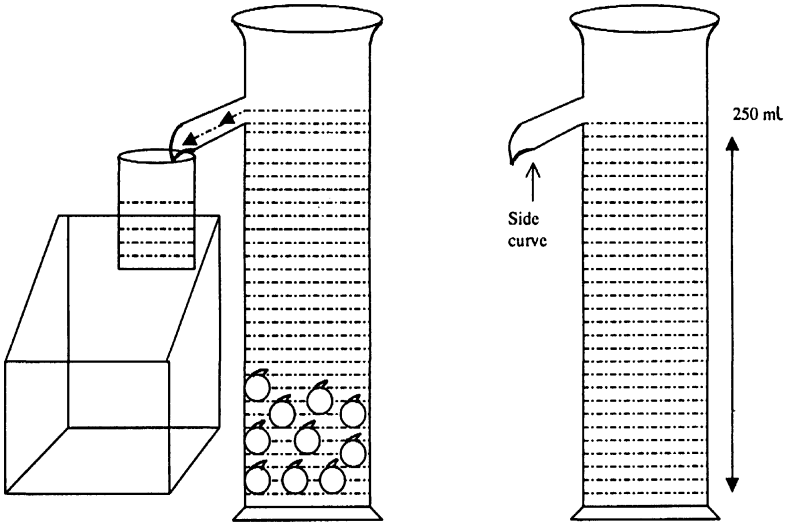


Fig 4. Measurement of seed volume by water displacement method for computation of seed diameter

with the help of cylinder with a side outlet (Fig. 4). Water was filled in the cylinder, which accommodated 250 ml up to the level of the side outlet. Water excess than 250 ml drained out from the side outlet. Seeds were then placed in the cylinder, the water drained out due to the addition of seeds to the water contained in the cylinder was collected into a beaker of known weight. The weight of the water displaced from the cylinder was recorded.

Volume of seeds (ml) = (Weight of beaker + water g.)- Weight of beaker (g).

From this volume of seed, the diameter of seed was computed by using the following formula

Diameter (d) = $\sqrt[3]{(\text{Volume} \times 6/\pi)}$

Surface area was calculated by $\pi \times d^2$

From this surface to volume ratio of seeds was calculated Correlation was drawn between different measured diameters and the diameter computed and also different surface to volume ratios.

RESULTS

CHAPTER IV

RESULTS

4.1 Field evaluation

4.1.1 Plant stands

4.1.1.1 Farmer-1

The two farmers used different seed rates. Farmer-1 used a seed rate of 25 kg ha^{-1}. Viability of the seeds he used for sowing was 97% (Table 15a). Taking into consideration the seed rate and seed viability, the plant stand should have been 21 plants/m^2. However, there were only 12 plants/m^2 before irrigation (Table 2b). The soil moisture content at that stage of observation, was 22% at 0-5 cm and 31% at 5-10 cm soil depth (Table 2a). Irrigation increased the soil moisture content both in the 0-5 and 5-10 cm depth but there was a marginal effect on increase in plant stands by only 2-3 plants/m^2, which was not significant. However, at the time of harvest the number of plants/m^2 in non irrigated treatment decreased and the number was nearly half i.e., 8 plants/m^2. Plant stands in the field of Farmer-1 were 43% lower than the expected plant stand computed on the basis of the seed rate used and viability of seeds. In the irrigated treatment the plant stand was double of the non irrigated treatment.

4.1.1.2 Farmer-2

Farmer-2 used a seed rate of 43 Kg ha^{-1} the viability of these seeds was 100% (Table 15a). This seed rate should have produced a plant

Table 2: (a) Soil moisture content at the time of sowing, and its effect on (b) plant stand/m^2, (c) crop growth, (d) shoot mass, seed yield, and HI% in the experiment on farmer's field

a: Soil moisture content (%)

Time	Soil depth (Cm)	Farmer 1	Farmer 2
At sowing	0-5	22.20	15.9
	5-10	31.0	22.3
Two hours after irrigation/rain (10 DAS)	0-5	31.8	30.1
	5-10	34.3	32.7

(b) Plant stands/m^2, (c)growth parameters and (d) yield data respectively

Time	Farmer 1				Farmer 2	
	No irrigation	S.Em	Irrigation	S.Em	No irrigation	S.Em
b: Plant stands/m^2						
Ten DAS	11.8	2.18	10.8	2.44	4.3	0.7
Twenty DAS	15.2	2.67	14	2.66	16.7	2.67
At harvest	8	0.63	15	3.16	11.4	1.46
c: Growth parameters						
LAI sample 1	3.0 [1]	0.7	4.0 [1]	0.8	1.3 [2]	0.49
LAI sample 2	2.8 [3]	0.24	2.4 [3]	1.33	0.9 [3]	0.97
CGR (g m^{-2} wk^{-1})	4.32	1.77	9.27	5.36	2.11	1.57
RGR (g g^{-1} day^{-1})	0.1	0.02	0.2	0.1	0.1	0.06
d: Yield data						
Shoot mass (Kg ha^{-1})	1251	143	1785	94	1528	0.99
Yield (Kg ha^{-1})	526	13.9	913	6.1	789	3.7
HI (%)	42	2.9	51	2.4	51	0.87

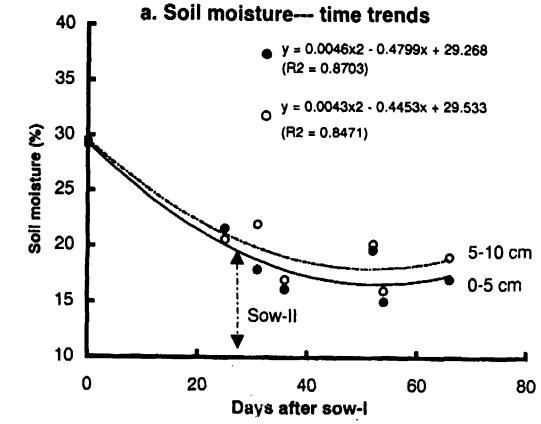
1 = Sampled at 85 DAS 2 = Sampled at 75 DAS
3 = Sampled 10 days after sample 1

stand of 35 plants/m^2 (Table 2b). At 10 DAS there were only 4 plants/m^2 i.e., 11% of the expected plant stand. The soil moisture content at sowing was 16% at 0-5 cm and 22% at 5-10 cm soil depth (Table 2a). Subsequently, at 20 DAS, the plant population increased to 17/m^2 after a rainfall of 50.4 mm, which occurred seven days after sowing. This rainfall had increased soil moisture to 33%. Even then, plant stand remained, lower by 51% compared the expected number of plants. By the time of harvest, the number of plants/m^2, decreased to 11 plants/m^2 being nearly 1/3rd of the expected stand.

4.1.1.3 ICRISAT Center

At ICRISAT center the effect of sowing dates, used to create treatment differences in soil moisture content at sowing time, was studied on germination and stand establishment of chickpea. The soil moisture content at the time of the three sowing dates (as estimated from the regression of progressive delay in time of periodic sampling and the soil moisture content) at 0-5 and 5-10 cm soil depth are given in Fig. 5a and 5b. Soil moisture decreased progressively with delay in sowing and the rainfall that had occurred 9 DAS-II was effective in increasing soil moisture by 23% at 0-5 cm and 5-10 cm soil depth.

There were 36 plants/m^2 at 10 DAS in both sow-I and sow-II compared to 15 plants/m^2 in sow-III. Plant stand in sow-III was lower by 58%



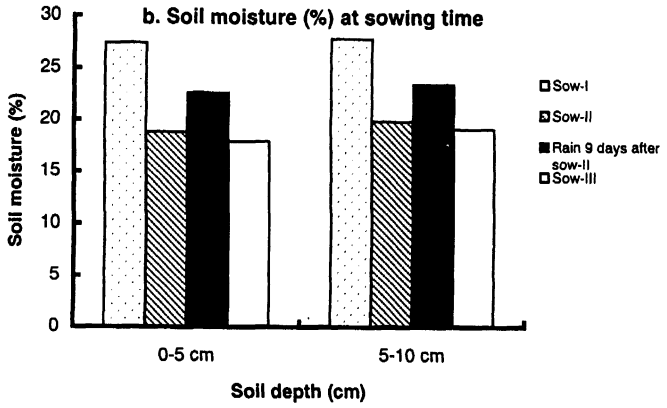


Fig. 5 (a) Changes in soil moisture at 0-5 and 5-10 cm soil depth with time on progressively drying seed beds beginning after sow-I
(b) Soil moisture at 0-5 cm and 5-10 cm soil depth at three sowing dates and at 40 DAS I after an event of rainfall (28mm) on 9/12/97 which was 9 days after sow-II

Table 3: Effect of sowing date, irrigation, genotype and their interaction on plant stands/m2 at 10 days after sowing

a. Sowing date x Irrigation

Irrigation	Sowing date			Mean for irrigation
	Sow I	Sow II	Sow III	
No Irrigation	35.8	34.2	6.5	25.5
Irrigaiton	36.9	38.3	24.2	33.1
S.Em		0.92		0.47
LSD		2.71		2.86'
Mean for sowing date	36.4	36.3	15.3	
S.Em		0.69		
LSD		1.96		

b. Sowing date x Genotype

Sowing date	Genotype			
	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	34.2	36.8	37.8	36.7
Sowing II	37.2	37.5	35.3	35.2
Sowing III	15.3	14.2	15	16.8
S.Em		NS		
LSD		NS		
Mean for genotype	28.9	29.5	29.4	29.6
S.Em		NS		
LSD		NS		

c. Irrigation x Genotype

Irrigation	Genotype			
	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	24.3	26.8	25.0	26.0
Irrigaiton	33.4	32.2	33.8	33.1
S.Em		NS		
LSD		NS		

d. Sowing date x Irrigation x Genotype

Sowing Date	Irrigation	Genotype			
		Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	32.3	37.3	37.3	36.3
	Irrigation	36.0	36.3	38.3	37.0
Sowing II	No Irrigation	35.7	37.0	32.0	32.3
	Irrigation	38.7	38.0	38.7	38.0
Sowing III	No Irrigation	5.0	6.0	5.7	9.3
	Irrigation	25.7	22.3	24.3	24.3
S.Em			NS		
LSD			NS		

LSD significant at 1% level

'at 10% level

than expected (Table 3a). Effect of sowing date was significant on plant stand. In the first two sowing dates plant stand was similar and closer to the expected or potential plant stand, but in sow-III the plant stands were less than 50% of the expected. Irrigation increased plant stand by 22% but the effect was significant only at 10% probability levels. The interaction between irrigation and sowing date was significant and showed that while in sow-I irrigation effect was not significant, but significant in sow-II and sow-III. It increased plant stand by 11% in sow-II and by 71% in sow-III (from 6 plants/m^2 to 24 plants/m^2). Differences between genotypes and other interactions were not significant (Tables 3b,3c and 3d).

At maturity, the plant stand decreased compared to plant stand at 10 DAS. In sow-I and sow-II decrease in plant stand was 24% whereas in sow-III the decrease was only 7% (Table 3 and 4). At harvest, plant stands in sow-I and sow-II were similar, but there was significant reduction in sow-III in which the plant stands were only half of sow-I and sow-II (Table 4a). All other interactions were not significant.

4.1.2 Days to flowering

Sowing date had significant effect on days to flowering (Table 5). Flowering was earlier by 1-2 days in sow-II compared to sow-I and sow-III. The genotypes also differed significantly in days to flowering. Among the four

Table 4: Effect of sowing date, irrigation, genotype and their interaction on plant stands/m2 at harvest

a. Sowing date x Irrigation

	Sowing date			Mean for
Irrigation	Sow I	Sow II	Sow III	irrigation
No Irrigation	26.3	28.3	6.0	20.2
Irrigaiton	28.1	28.0	21.8	26.0
S.Em		1.51		1.32
LSD		6.33		8.01 ′
Mean for sowing date	27.2	28.2	13.9	
S.Em		0.64		
LSD		1.81		

b. Sowing date x Genotype

	Genotype			
Sowing date	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	26.5	27.8	27.7	26.8
Sowing II	28.2	30.2	28.3	26.0
Sowing III	15.2	13.7	12.5	14.3
S.Em		NS		
LSD		NS		
Mean for genotype	23.3	23.9	22.8	22.4
S.Em		NS		
LSD		NS		

c. Irrigation x Genotype

	Genotype			
Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	19.3	21.0	20.2	20.3
Irrigaiton	27.2	26.8	25.4	24.4
S.Em		NS		
LSD		NS		

d. Sowing date x Irrigation x Genotype

		Genotype			
Sowing Date	Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	24.3	28.0	27.0	26.0
	Irrigation	28.7	27.7	28.3	27.7
Sowing II	No Irrigation	28.7	30.3	27.7	26.7
	Irrigation	27.7	30.0	29.0	25.3
Sowing III	No Irrigation	5.0	4.7	6.0	8.3
	Irrigation	25.3	22.7	19.0	20.3
S.Em			NS		
LSD			NS		

LSD significant at 1% level

′ at 10% level

Table 5: Effect of sowing date, genotype and their interaction on days to flowering

Sowing date	Genotype				Mean of Sowing date
	Farmer 1	Farmer 2	Annigeri	ICCV2	
Sowing I	45	46	46	36	43
Sowing II	45	46	44	35	43
Sowing III	47	46	46	37	44
S.Em		0.4#			0.2
LSD		1.18#			0.59
Mean of genotype	46	46	45	36	
S.Em		0.23			
LSD		0.68			

LSD significant at 1% level
at 10% level

genotypes studied, ICCV2 flowered 9-10 days earlier compared to the rest. All genotypes flowered earlier in sow-II compared to sow-I and sow-III.

4.1.3 Days to maturity

Irrigation had a significant effect in delaying maturity by two days. The interaction between sowing date x irrigation was not significant (Table 6a). Effect of sowing date on days to maturity was significant. Sow-II matured earlier compared to sow-I and sow-III. The genotypic differences in maturity were significant. The genotypes, in order of increasing days to maturity, varied as Farmer 2>ICCV2>Farmer 1>Annigeri. The interaction between sowing date and genotype was significant because there was a difference in the magnitude of response between genotypes (Table 6b). The interaction between irrigation and genotype was significant because in Annigeri no difference between irrigated and non irrigated treatments was observed while the effect was significant in other three genotypes (Table6c). Interaction of sowing date x Irrigation x genotype, was not significant.

4.1.4 Growth analysis

4.1.4.1 Leaf area index (LAI)

In the case of farmer-1 field leaf area index was higher in the irrigated treatments in the first sample. LAI decreased progressively with time in both irrigated and non irrigated treatments (Table 2c). In the case of farmer-

Table 6: Effect of sowing date, irrigation, genotype and their interaction on days to maturity

a. Sowing date x Irrigation

	Sowing date			Mean for
Irrigation	Sow I	Sow II	Sow III	irrigation
No Irrigation	83.5	76.6	86.1	82.1
Irrigaiton	85.3	79.3	88.7	84.4
S.Em		NS		0.09
LSD		NS		0.52
Mean for sowing date	84.4	77.9	87.4	
S.Em		0.17		
LSD		0.50		

b. Sowing date x Genotype

	Genotype			
Sowing date	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	86.2	82.0	86.5	83.0
Sowing II	80.3	74.8	80.5	76.0
Sowing III	86.2	82.0	92.8	88.5
S.Em		0.35		
LSD		0.99		
Mean for genotype	84.2	79.6	86.6	82.5
S.Em		0.20		
LSD		0.57		

c. Irrigation x Genotype

	Genotype			
Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	83.6	77.4	86.3	80.9
Irrigaiton	84.9	81.8	86.9	84.1
S.Em		0.26		
LSD		0.74		

d. Sowing date x Irrigation x Genotype

		Genotype			
Sowing Date	Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	85.3	80.3	86.7	81.7
	Irrigation	87.0	83.7	86.3	84.3
Sowing II	No Irrigation	79.7	72.7	80.3	73.7
	Irrigation	81.0	77.0	86.7	78.3
Sowing III	No Irrigation	85.7	79.3	92.0	87.3
	Irrigation	86.7	84.7	93.7	89.7
S.Em			NS		
LSD			NS		

LSD significant at 1% level

Table 7: Effect of sowing date, irrigation, genotype and their interaction on leaf area index (LAI) at 40 DAS

a. Sowing date x Irrigation

Irrigation	Sowing date			Mean for irrigation
	Sow I	Sow II	Sow III	
No Irrigation	2.7	2.3	0.4	1.8
Irrigaiton	3.2	2.6	0.9	2.2
S.Em		NS		0.06*
LSD		NS		0.35*
Mean for sowing date	3.0	2.5	0.7	
S.Em		0.11		
LSD		0.32		

b. Sowing date x Genotype

Sowing date	Genotype			
	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	2.9	1.9	3.1	4.0
Sowing II	2.0	2.5	2.4	3.0
Sowing III	0.4	0.6	0.8	0.8
S.Em		0.22		
LSD		0.64		
Mean for genotype	1.8	1.7	2.1	2.6
S.Em		0.13		
LSD		0.37		

c. Irrigation x Genotype

Irrigation	Genotype			
	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	1.6	1.6	1.9	2.3
Irrigaiton	2.0	1.8	2.3	2.9
S.Em		NS		
LSD		NS		

d. Sowing date x Irrigation x Genotype

Sowing Date	Irrigation	Genotype			
		Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	2.6	1.7	3.1	3.6
	Irrigation	3.2	2.2	3.0	4.3
Sowing II	No Irrigation	1.9	2.6	2.1	2.8
	Irrigation	2.2	2.3	2.7	3.2
Sowing III	No Irrigation	0.3	0.4	0.6	0.5
	Irrigation	0.5	0.8	1.1	1.1
SEM			NS		
LSD			NS		

LSD significant at 1% level

* at 5% level

2 also, leaf area decreased progressively with time between sample 1 (75 DAS) and sample 2 (7 days after sample 1).

At ICRISAT Center LAI at 40 DAS was significantly higher in the irrigated than in the non-irrigated treatment. Also LAI decreased significantly between sow-I, sow-II and sow-III (Table 7a). Interaction between sowing date and irrigation was not significant. Genotypes differed significantly in LAI, ICCV2 produced largest LAI followed by Annigeri, Farmer 1 and Farmer 2. Interaction between sowing date x genotypes was significant (Table 7b), because genotypic differences between varieties were significant in sow-II and sow-I but not significant in sow-III. All other effects were not significant. At 47 DAS, sowing dates differed significantly in LAI, which decreased progressively with delay in sowing date. LAI was the highest in sow-I and lowest in sow-III (Table 8a). All other effects were not significant in LAI at 47 DAS.

4.1.4.3 Crop growth rate (CGR)

CGR (g m^{-2} wk^{-1}) was higher in irrigated treatment in the farmer 1 and was least in the field of farmer-2 (Table 2c). At ICRISAT Center sowing date had a significant effect on CGR. It was 85-89% lower in sow-III than in sow-I and sow-II (Table 9a). The differences between genotypes were not significant in CGR. All other effects and interactions were also not significant.

Table 8: Effect of sowing date, irrigation, genotype and their interaction on leaf area index (LAI) at 47 DAS

a. Sowing date x Irrigation

Irrigation	Sowing date			Mean for irrigation
	Sow I	Sow II	Sow III	
No Irrigation	4.4	3.1	0.7	2.6
Irrigaiton	4.6	3.1	1.0	2.9
S.Em		NS		NS
LSD		NS		NS
Mean for sowing date	4.3	3.1	0.8	
S.Em		0.14		
LSD		0.41		

b. Sowing date x Genotype

Sowing date	Genotype			
	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	4.2	4.2	4.5	4.3
Sowing II	3.0	3.9	3.1	2.4
Sowing III	0.5	0.8	1.0	1.1
S.Em		NS		
LSD		NS		
Mean for genotype	2.5	3.0	2.9	2.6
S.Em		NS		
LSD		NS		

c. Irrigation x Genotype

Irrigation	Genotype			
	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	2.4	3.0	2.8	2.3
Irrigaiton	2.7	3.0	3.0	2.9
S.Em		NS		
LSD		NS		

d. Sowing date x Irrigation x Genotype

Sowing Date	Irrigation	Genotype			
		Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	3.9	3.9	4.0	4.1
	Irrigation	4.4	4.5	5.0	4.4
Sowing II	No Irrigation	2.8	4.2	3.4	2.0
	Irrigation	3.1	3.5	2.8	2.9
Sowing III	No Irrigation	0.4	0.7	0.9	0.8
	Irrigation	0.5	1.0	1.1	1.3
S.Em			NS		
LSD			NS		

LSD significant at 1% level

Table 9: Effect of sowing date, irrigation, genotype and their interaction on crop growth rate (CGR) (g m^{-2} wk^{-1}) between 40-47 DAS

a. Sowing date * Irrigation

	Sowing date			Mean for
Irrigation	Sow I	Sow II	Sow III	irrigation
No Irrigation	3.59	4.17	0.72	2.83
Irrigaiton	3.49	5.12	0.3	2.97
S.Em		NS		NS
LSD		NS		NS
Mean for sowing date	3.54	4.65	0.51	
S.Em		0.26		
LSD		0.75		

b. Sowing date x Genotype

	Genotype			
Sowing date	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	2.97	4.62	3.29	3.28
Sowing II	4.18	4.83	3.69	5.89
Sowing III	0.18	0.61	0.82	0.42
S.Em		NS		
LSD		NS		
Mean for genotype	2.44	3.35	2.6	3.19
S.Em		NS		
LSD		NS		

c. Irrigation x Genotype

	Genotype			
Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	2.36	3.13	3.15	2.67
Irrigaiton	2.54	3.58	2.06	3.72
S.Em		0.51#		
LSD		1.63#		

d. Sowing date x Irrigation x Genotype

		Genotype			
Sowing Date	Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	3.13	3.85	4.27	3.12
	Irrigation	2.82	5.39	2.32	3.45
Sowing II	No Irrigation	3.74	4.63	3.86	4.49
	Irrigation	4.63	5.04	3.53	7.28
Sowing III	No Irrigation	0.21	0.92	1.32	0.42
	Irrigation	0.16	0.31	0.33	0.42
S.Em			NS		
LSD			NS		

LSD significant at 1% level

significant at 10% level

4.1.4.4 Relative growth rate (RGR)

RGR (g g^{-1} day^{-1}) was greater in the irrigated treatment in the field of farmer-1 and was smaller in the field of farmer-2 (Table 2c). At ICRISAT Center sowing date had significant effect on (RGR) (Table 10a). The values for RGR were 45 and 29% less in sow-III compared to sow-I and sow-II, respectively. In sow-I the RGR was high compared to others. Interaction between sowing date and irrigation was significant. Irrigation increased the RGR by 47% in sow-I and by 15% in sow-II. In sow-III irrigation decreased RGR by 74%. All other effects were not significant.

4.1.5 Total number of branches per plant

Sowing date increased significantly the total number of branches per plant (Table 11a). Total number of branches, especially in sow-III, were more by 41% compared to sow-II and by 28% compared to sow-I. Interaction between sowing date and irrigation was significant, irrigation increased number of branches significantly in sow-I and sow-II but decreased the number in sow-III significantly (Table 11a). Genotypes differed significantly in number of branches. Annigeri produced more branches compared to Farmer 2 (10% less), Farmer 1 (16% less) and ICCV2 (52% less) (Table 11b). Interaction between sowing date and genotype was significant at 5% level because in all

Table 10: Effect of sowing date, irrigation, genotype and their interaction on relative growth rate (RGR) ($g\ g^{-1}\ day^{-1}$) between 40-47 DAS

a. Sowing date x Irrigation

	Sowing date			Mean for
Irrigation	Sow I	Sow II	Sow III	irrigation
No Irrigation	0.2	0.2	0.25	0.22
Irrigaiton	0.37	0.24	0.07	0.22
S.Em	0.032			NS
LSD	0.091			NS
Mean for sowing date	0.28	0.22	0.16	
S.Em		0.03		
LSD		0.07		

b. Sowing date x Genotype

	Genotype			
Sowing date	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	0.27	0.42	0.22	0.23
Sowing II	0.22	0.2	0.17	0.28
Sowing III	0.13	0.18	0.22	0.12
S.Em	0.05#			
LSD	0.14#			
Mean for genotype	0.19	0.27	0.2	0.21
S.Em		NS		
LSD		NS		

c. Irrigation x Genotype

	Genotype			
Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	0.22	0.23	0.24	0.17
Irrigaiton	0.18	0.3	0.17	0.25
S.Em	NS			
LSD	NS			

d. Sowing date x Irrigation x Genotype

		Genotype			
Sowing Date	Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	0.3	0.22	0.16	0.11
	Irrigation	0.23	0.62	0.28	0.35
Sowing II	No Irrigation	0.21	0.18	0.17	0.25
	Irrigation	0.23	0.23	0.17	0.32
Sowing III	No Irrigation	0.14	0.3	0.39	0.16
	Irrigation	0.07	0.07	0.06	0.07
S.Em		NS			
LSD		NS			

LSD significant at 1% level

at 10% level

Table 11: Effect of sowing date, irrigation, genotype and their interaction on total number of branches per plant

a. Sowing date x Irrigation

Irrigation	Sowing date			Mean for irrigation
	Sow I	Sow II	Sow III	
No Irrigation	25.8	19.7	52.6	32.7
Irrigaiton	26.2	23.3	19.7	23.1
S.Em		3.5		NS
LSD		11.62		NS
Mean for sowing date	26	21.5	36.2	
S.Em		2.11		
LSD		6.02		

b. Sowing date x Genotype

Sowing date	Genotype			
	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	31.3	27.7	27	18.1
Sowing II	22.4	24.1	23.3	16.2
Sowing III	40	35.7	53.5	15.4
S.Em		4.22*		
LSD		12.04*		
Mean for genotype	31.2	29.2	34.6	16.6
S.Em		2.44		
LSD		6.95		

c. Irrigation x Genotype

Irrigation	Genotype			
	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	38.1	33.2	42	17.6
Irrigaiton	24.3	25.2	27.2	15.6
S.Em		NS		
LSD		NS		

d. Sowing date x Irrigation x Genotype

Sowing Date	Irrigation	Genotype			
		Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	32	27.6	25.5	18.2
	Irrigation	30.6	27.9	28.5	18
Sowing II	No Irrigation	22.1	20.5	19.9	16.4
	Irrigation	22.7	27.7	26.6	16
Sowing III	No Irrigation	60.3	51.5	80.4	18.1
	Irrigation	19.7	19.9	26.6	12.8
S.Em			6.24*		
LSD			17.94*		

LSD significant at 1% level

* 5% level

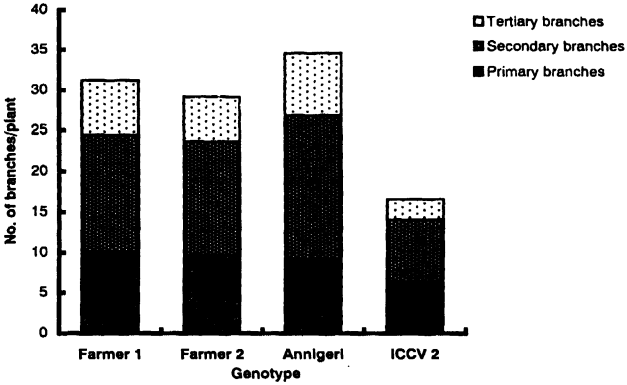


Fig. 6 Total number of branches and its components in all the four genotypes

the genotypes late sowing resulted in more number of branches, except in ICCV2. In all the genotypes the per cent of secondary branches as total number of branches was more compared to primary and tertiary branches (Fig. 6). Secondary branches contributed to 46-51%, primary branches to 26-38% and tertiary branches to 15-22% of total number of branches in different genotypes.

4.1.6 Dry matter production

In fields of farmers shoot mass (Kg ha^{-1}) production was only 1/3rd (Table 2d) compared to ICRISAT Center (Table 12). Irrigation increased the shoot mass in the field of farmer-1. The shoot mass in farmer-2 was lesser compared to farmer-1. At ICRISAT Center, although the decrease in shoot mass in response to drought, in non irrigated treatment compared to irrigated treatment, was 13%, which was greater than the 11% in shoot mass between sow-I and sow-II, yet this effect was not significant (Table 12a). There was a significant and positive decrease in shoot mass with progressive delay in sowing. Between sow-I and sow-II, the decrease was 11% but it was 75% between sow-I and sow-III, and 72% from sow-II to sow-III. All other effects were not significant.

4.1.7 Yield

In the field of farmer-1 irrigation increased seed yield (913 Kg ha^{-1}) compared to non irrigated treatment (526 Kg ha^{-1}), which was almost half

Table 12: Effect of sowing date, irrigation, genotype and their interaction on shoot mass (Kg ha^{-1})

a. Sowing date x Irrigation

	Sowing date			Mean for
Irrigation	Sow I	Sow II	Sow III	irrigation
No Irrigation	3355	3124	401	2293
Irrigaiton	3556	3007	1301	2627
S.Em	162.8			NS
LSD	609.9			NS
Mean for sowing date	3455	3066	851	
S.Em		82.3		
LSD		234.6		

b. Sowing date x Genotype

	Genotype			
Sowing date	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	3620	3601	3528	3072
Sowing II	2965	3099	3391	2806
Sowing III	864	973	697	870
S.Em	NS			
LSD	NS			
Mean for genotype	2483	2558	2539	2250
S.Em		95.1*		
LSD		270.9*		

c. Irrigation x Genotype

	Genotype			
Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	2174	2365	2484	2150
Irrigaiton	2792	2558	2539	2250
S.Em	NS			
LSD	NS			

d. Sowing date x Irrigation x Genotype

		Genotype			
Sowing Date	Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	3440	3453	3468	3058
	Irrigation	3800	3749	3587	3086
Sowing II	No Irrigation	2803	3215	3657	2820
	Irrigation	3127	2984	3125	2793
Sowing III	No Irrigation	279	426	327	573
	Irrigation	1450	1520	1067	1167
S.Em		NS			
LSD		NS			

LSD significant at 1% level
* at 5%level

of the irrigated treatment (Table 2d). In case of farmer-2, rainfall had occurred soon after sowing and the yield was 789 Kg ha^{-1} higher than the rainfed yield in case of farmer-1. Seed yield in farmer's fields were nearly 50% of the yield at ICRISAT center (Table 13).

At ICRISAT center, there was a significant effect of sowing date on the seed yield. The seed yield was more (1783 Kg ha^{-1}) in sow-I and decreased progressively with delay in sowing (Table 13a). The difference in yield between sow-I and sow-II was not significant. Irrigation had no significant effect on seed yield. Interaction between sowing date and irrigation was significant because the seed yield increased by 75% upon irrigation in sow-III (Table 13a). Even though the genotypic differences were not significant, Annigeri produced more yield compared to the other three genotypes (Table 13b). Interaction between sowing date and genotype was significant because the yield in genotype Farmer 1 was significantly different between sow-I, sow-II and sow-III, but was similar in the other three genotypes. All other effects were not significant.

Primary branches contributed more to the total yield in Farmer 2. But in genotypes Farmer 1 and Annigeri, the secondary branches contributed more towards seed yield. In ICCV2 both primary and secondary branches contributed equally to the seed yield (Fig. 7).

Table 13 Effect of sowing date, irrigation, genotype and their interaction on seed yield (Kg ha ^{1})

a. Sowing date x Irrigation

	Sowing date			Mean for
Irrigation	Sow I	Sow II	Sow III	Irrigation
No Irrigation	1730	1701	93	1175
Irrigation	1836	1594	369	1266
S Em	93 9*			
LSD	326 2*			
Mean for sowing date	1783	1648	231	
S Em		53 0		
LSD		151 1		

b. Sowing date x Genotype

	Genotype			
Sowing date	Farmer 1	Farmer 2	Annigen	ICCV2
Sowing I	1879	1803	1935	1515
Sowing II	1519	1620	1914	1537
Sowing III	206	260	92	365
S Em	106 0*			
LSD	302 2*			
Mean for genotype	1201	1228	1314	1139
S Em		NS		
LSD		NS		

c. Irrigation x Genotype

	Genotype			
Irrigation	Farmer 1	Farmer 2	Annigen	ICCV2
No Irrigation	1120	1179	1304	1095
Irrigation	1283	1277	1324	1183
S Em	NS			
LSD	NS			

d. Sowing date x Irrigation x Genotype

		Genotype			
Sowing Date	Irrigation	Farmer 1	Farmer 2	Annigen	ICCV2
Sowing I	No Irrigation	1789	1707	1915	1509
	Irrigation	1970	1899	1956	1520
Sowing II	No Irrigation	1528	1750	1961	1566
	Irrigation	1510	1490	1868	1508
Sowing III	No Irrigation	43	80	36	211
	Irrigation	368	441	149	519
S Em		NS			
LSD		NS			

LSD significant at 1% level

* at 5% level

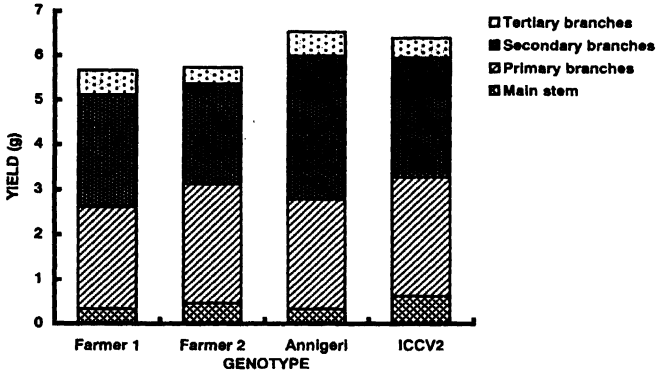


Fig. 7 Contribution of yield by different types of branches in all the four genotypes

4.1.8 Harvest index (HI%)

HI(%) was high in case of farmer-1 field in irrigated treatments (51%) compared to the non irrigated treatment (42%) (Table 2d). In the case of farmer-2 it was 51% (Table 2d). At ICRISAT Center the HI (%) was high in sow-II by 4% compared to sow-I and 61% higher than in sow-III (Table 14a). A 6% increase in HI was observed due to irrigation, which was significant at 5% probability. Response to irrigation in HI (%) of late sown crop, sow-III was large (33% more) and significant at 10% level compared to sow-I and sow-II. Genotypic differences were significant because ICCV2 had a higher HI (47%) compared to the other three genotypes (Table 14b). Interaction between sowing date and genotype was significant because the genotypic differences between sow-I and sow-II were not significant and significant between sow-I and sow-III and between sow-II and sow-III.

4.2 Laboratory evaluation

4.2.1 physical and biochemical seed characteristics

In most of the traits the differences between the genotypes farmer 1 and farmer 2 were small and non significant (Table 15a).

4.2.1.1 Seed moisture content

Genotypes differed significantly in seed moisture content, and varied as: ICCV2> Annigeri > farmer 1=farmer 2 (Table 15a).

Table 14 Effect of sowing date, irrigation, genotype and their interaction on harvest index (HI)%

a. Sowing date x Irrigation

	Sowing date			Mean for
Irrigation	Sow I	Sow II	Sow III	irrigation
No Irrigation	51.3	54.3	16 9	40 8
Irrigation	51 4	53 1	25 1	43 2
S Em		1 86#		0 32*
LSD		5.31#		1 97*
Mean for sowing date	51.3	53 7	21 0	
S Em		1.59		
LSD		4.53		

b. Sowing date x Genotype

	Genotype			
Sowing date	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	51 7	50 0	54 7	49 0
Sowing II	51.3	52 3	56.5	54 7
Sowing III	19 0	21 0	8 0	36 0
S Em		3 18		
LSD		9 06		
Mean for genotype	40 7	41 1	39 7	46 6
S Em	1 84*			
LSD	5 23*			

c Irrigation x Genotype

	Genotype			
Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
No Irrigation	40 4	40 1	38 7	44 1
Irrigation	40 9	42 1	40 8	49 0
S Em		NS		
LSD		NS		

d. Sowing date x Irrigation x Genotype

		Genotype			
Sowing Date	Irrigation	Farmer 1	Farmer 2	Annigeri	ICCV2
Sowing I	No Irrigation	51 7	49.3	54 7	49 3
	Irrigation	51 7	50 7	54 7	48 7
Sowing II	No Irrigation	54.3	54 3	53.3	55.3
	Irrigation	48.3	50.3	59 7	54 0
Sowing III	No Irrigation	15.3	16 7	8 0	27 7
	Irrigation	22 7	25.3	8 0	44.3
S Em			NS		
LSD			NS		

LSD significant at 1% level
* at 5% level
# at 10% level

Table 15 : Genotypic differences in (a) physical and biochemical seed characteristics of four genotypes of chickpea and (b) germination (%) at 20% and 22% moisture levels in laboratory studies

a. Physical and bio chemical characteristics

Characteristic	Genotype				S.Em	LSD
	Farmer 1	Farmer 2	Annigeri	ICCV2		
Seed moisture content(%)	9.39	9.45	8.63	9.72	0.018	0.061
Hundred seed weight (g)	15.61	15.29	22.78	25.18	0.400	1.38
Surface to volume ratio (cm^2 cm^{-3})	9.67	10.02	8.28	8.06	0.075	0.260
Germination (%) in laboratory	96.6	100	100	98.3	NS	NS
Rate of uptake (g/100seed/h)	12.46	11.17	9.68	5.17	0.373	1.29
Total uptake (g/100 seed)	95.5	96.2	102.1	113.6	2.11	7.29
Protiens (%)	18.27	19.2	20.23	22.1	0.458	1.59
Total soluble sugars(%)	4.41	4.62	5.12	5.37	0.093	0.320
Oil content (%)	5.65	5.61	5.25	5.15	0.087	0.300
Starch (%)	47.27	48	46.87	48.8	NS	NS

b. Effects of soil moisture, genotype and their interaction on seed germination

Germination percent	Genotype				Mean for moisture level
	Farmer 1	Farmer 2	Annigeri	ICCV2	
Germination (%) at 20% moisture	20	0	5	0	6.3
Germination (%) at 22% moisture	40	80	35	20	43.7
S.Em		11.6			5.79
LSD		39			19.35
Mean for genotype	30	40	20	10	
S.Em		8.2			
LSD		27.4			

4.2.1.2 Hundred seed weight

Hundred seed weight was significantly different among the genotypes, being the highest for ICCV2 and varied as ICCV2 > Annigeri > farmer 1=farmer 2 (Table 15a).

4.2.1.3 Surface to volume ratio

The surface to volume ratio was the highest in the genotype farmer 2, genotypic variation in the order of: farmer 2 > farmer 1 > Annigeri = ICCV2 (Table 15a).

4.2.1.4 Germination percent

Germination percent in all the four genotypes, tested in laboratory was very high and ranged between 97-100% and the small difference between the genotypes was not significant (Table 15a).

4.2.1.5 Kinetics of water uptake

The uptake of water was most rapid and linear in the first 4 to 6.5 hours of seed soaking (Fig. 8a) and then declined with time. ICCV2 imbibed more water with time compared to other genotypes and the differences were significant and varied as ICCV2 > Annigeri > farmer 1=farmer 2 (Table 15a). During this first phase (Phase I) all genotypes absorbed 86%-94% of final saturated seed moisture content. Very little water

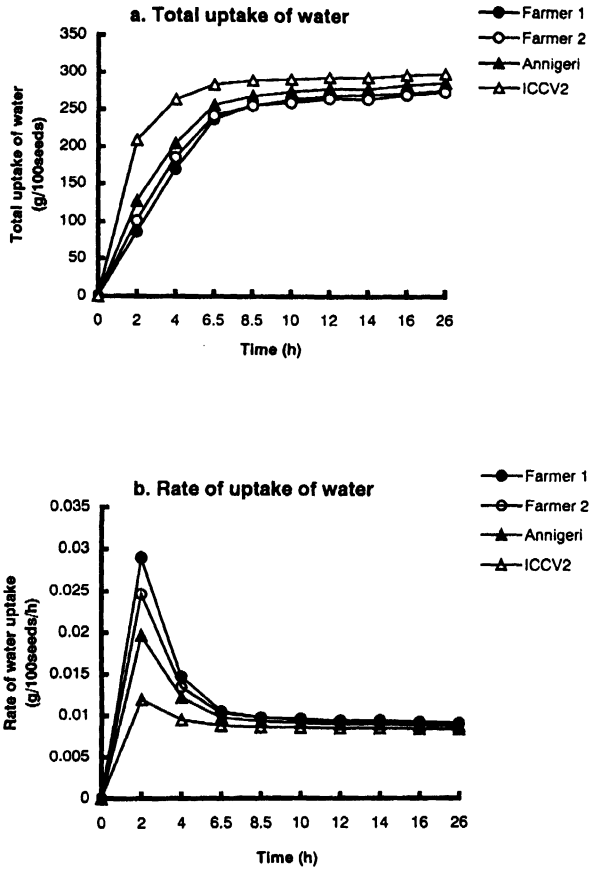


Fig. 8 Relationship of time with (a) total uptake of water (g/100seeds) and (b) rate of water uptake (g/100seeds/h)

was absorbed in phase II. Seeds were taken as germinated when white tip (part of radicle) was visible. These observations were taken between 6.5 hours to 26 hours.

The rate of uptake of water was most rapid in farmer 1 and ~~the~~ it differed significantly and genotypes varied in the order of farmer 1 > farmer 2 > Annigeri > ICCV2 (Fig. 8b, Table 15a).

4.2.1.6 Biochemical analysis

Genotypic differences in seed protein (%), oil (%) and total soluble sugars (TSS) were significant (Table 15b). Starch content between the genotypes ranged from 47-49%, but differences between genotypes were not significant. ICCV2 had higher protein, TSS and starch content, compared to other genotypes. The genotypic differences in per cent of oil content were opposite to the other metabolites. The genotype farmer 1 which had lower protein and TSS content, had high oil content.

4.2.2 Glass house experiment

Germination and emergence of seeds (studied at sub-optimal soil moisture content of 20% and 22% w/w) showed that it was high at 22% moisture (w/w) compared to 20% (w/w) soil moisture content. Among the genotypes farmer 2 had significantly the highest germination per cent of seeds

than the other varieties. The interaction between genotypes x moisture content was significant because of the significant difference in moisture treatment in germination were significant only in the genotype farmer 2, compared to the other three genotypes.

DISCUSSION

CHAPTER V

Discussion

In agriculture, irrespective of crops, i.e., food-fodder-feed, horticultural, medicinal or industrial crops, establishment of targeted plant stand is the single most dominant factor affecting crop production per unit area of land. Establishment of the required plant stand is, therefore, the most crucial factor to realize the maximum production potential of a given crop or its variety (genotype/cultivar). This is also very important for optimum utilization of available natural resources endowed in a given region, the land (soil type) and climatic conditions (rainfall, temperature, evaporation, solar radiation etc.) that prevail in a given region. These factors in turn determine the amount of economic returns that a farmer will accrue and the profitability of the enterprise.

To establish the needed plant density, it is important that the quantity of the seeds sown correspond to obtain the plant density that is being aimed. Once this agronomic management requirement is fulfilled, other factors that affect the germination and emergence of seeds sown, become important and influence the target plant density. These factors are:

1. Seed size -- A large variation is available in chickpea germplasm. It also has a strong implication in customer/consumer preferences and price.

2. Quality of seeds -- both the physical and the chemical quality
3. Adequate soil moisture at depth of sowing for seed germination
4. Pest and diseases that may result in the death of germinating seeds and seedlings.

These simple indices of quality traits are desirable for selection in the germplasm and incorporating the same in the adapted genetic backgrounds for improving the quality and thereby improving establishment of plant stand.

The objectives of my research were to study the effect of the first three factors on plant stand establishment in farmer's fields and to verify the results obtained in an experiment conducted on the experimental station at ICRISAT center.

From the present findings it is obvious that farmer-1 used a seed rate of 25 Kg ha^{-1} because the seed stock he had was small size (155 mg/seed). Perhaps this may be the reason for a poor plant stand of 10-11 plants/m^2 compared to other situations. As per the physical quality of the seed the farmer-1 should have used a seed rate of 48 Kg ha^{-1} in non irrigated and 56 Kg ha^{-1} in irrigated conditions provided the seed rate would have been calculated considering the wt of seed (mg), number of plants/m^2, germination % and field factor (Bleasdale, 1973).

In chickpea, empiricial experiments conducted at several locations with very diverse soil and climate (ranging from 17° N to 31° N latitudes in India) have shown that the optimum plant stand for obtaining maximum seed yields are around 3,30,000 plants/ha (Saxena, 1980).

The observed initial plant stands 10 DAS on both the farmer' fields were very poor and ranged from 4-12 plants/m^2 (Table 2b). At 20 DAS, plant stands increased but still were far below the optimum for maximum yield as these ranged between 15-17 plants/m^2. At harvest, the plant stands decreased further and ranged between 8-15 plants/m^2.

The reasons for poor plant stands in the case of farmer-1 were that he used a suboptimum seed rate of 25 kg ha^{-1}, which whould have given only 21 plants/m^2 under favourable soil moisture and disease and insect free conditions as the seed viability was high (97%). However, there were only 11-12 plants/m^2 at 10 DAS and before irrigation, which increased (after irrigation applied at 10 DAS) to 14-15 plants/m^2 at 20 DAS. There was no significant difference in the plant stand between the irrigated and non irrigated treatments, perhaps because the soil moisture at the time of sowing in the seed bed (22% at 0-5 cm and 31% at 5-10 cm depth) was adequate.

The decrease in plant stand at harvest to 8 plants/m^2 in the case of farmer-1 in non irrigated treatment seems to be due to drought because in the irrigated treatment plant stand increased to 15 from 14 plants/m^2. However, the plant stand was lower than the expected plant stand (21 plants/m^2) in the irrigated treatment in the case of farmer-1 probably due to factors other than soil moisture such as the soil-borne diseases (fusarium wilt and dry root rot) and the method of sowing. Farmer-1 used a country seed drill (***Gorru***) which could have dropped some seeds at shallower depths because of the presence of stones which did not permit uniform planting at one depth.

The poor plant stand in the case of farmer-2 (4 plants/m^2) seems to be related with inadequate soil moisture for germination. Soil moisture was around16% (at 0-5 cm) and 22% (at 5-10 cm), far below the critical soil moisture. Farmer had used adequate seed rate (43 kg ha^{-1}) which should have produced 35 plants/m^2 and the seed sown were perfectly viable (100% germination Table 5). Soil moisture at sowing time (16% at 0-5 cm and 22% at 5-10 cm) was far below the critical soil moisture (23-24%) for germination of seeds in a vertisol (Saxena *et al.*, 1983). The increase in plant stand to 17 plants/m^2 at 20 DAS, was attributed to raised soil moisture of 30% (at 0-5 cm) and 33% (at 5-10 cm) due to the event of rain, which occurred one week after sowing. Even then the plant stand remained lower by 51% than the expected. A strong

reason could be that the farmer used a broadcast method for sowing, which could have dropped many seeds on the soil surface or at very shallow depths. This might have also lowered the degree of seed-soil contact resulting in poor plant stands. At harvest, there were only 11 plants/m^2 and the decrease between 20 DAS and harvest could be the combined effect of progressive decrease in soil moisture with time and the incidence of soil borne diseases.

It is quite interesting to note that both the cultivars used by farmers recorded significantly higher germination percentage in the experimental site at ICRISAT center because of the uniform and optimum depth of sowing of 5-7 cm implemented by JD 7100 Cone Planter. At this center, a progressive delay in planting date was effective in achieving the objective of creating difference in soil moisture content, ranging from 18% to 27% in surface 0-5cm soil depth and 19-28% in 5-10 cm soil depth, at the time of sowing (Fig. 5b). Despite the rainfall (28 mm), which occurred 9 DAS-II, the soil moisture in sow-II remained lower than in sow-I. Soil water deficit reduced plant stand and is evident from lower plant stands in non irrigated than in the irrigated treatment in sow-II (Table 3a). The decline in plant stand at harvest, over initial stand 10 DAS, at ICRISAT center in sow-I and Sow-II (to 76% of the initial plant stands at 10 DAS) (Table 4a) seems to be related to disease incidence. Soil moisture seems to be sufficient for seed germination because there was no difference

between the two irrigation treatments. The initial plant stands (10 DAS), were similar in sow-I and sow-II and identical to the expected population of 36 plants/m2, but were only 46% of the expected in sow-III.

In sow-III, the plant stands at harvest were nearly 90% of the initial plant stands at 10 DAS. The less relative decline of 10% in sow-III, compared to sow-I and sow-II (decline by 25%), may be because there were fewer plants/m^2, adequate soil moisture availability per plant and perhaps also lower disease incidence. The effect of irrigation on increasing plant stand was diluted at harvest because of other factors. The effect was apparent as the difference was significant at 0.09 (<10%) P (Table 4a).

The two farmer's varieties, in general, seem to germinate better from low soil moisture levels. The difference between the varieties was narrow in non irrigated treatment (Fig. 9b) which increased in the irrigated treatment (Fig. 9c).

At ICRISAT center, soil moisture at sowing was positively correlated with initial plant stand 10 DAS (Fig. 9a) and accounted for a significant and large variation (42%) in plant stand in the non irrigated treatment. When the moisture was not limiting, as in the irrigated treatment, only 17% variation in plant stand was accounted by soil

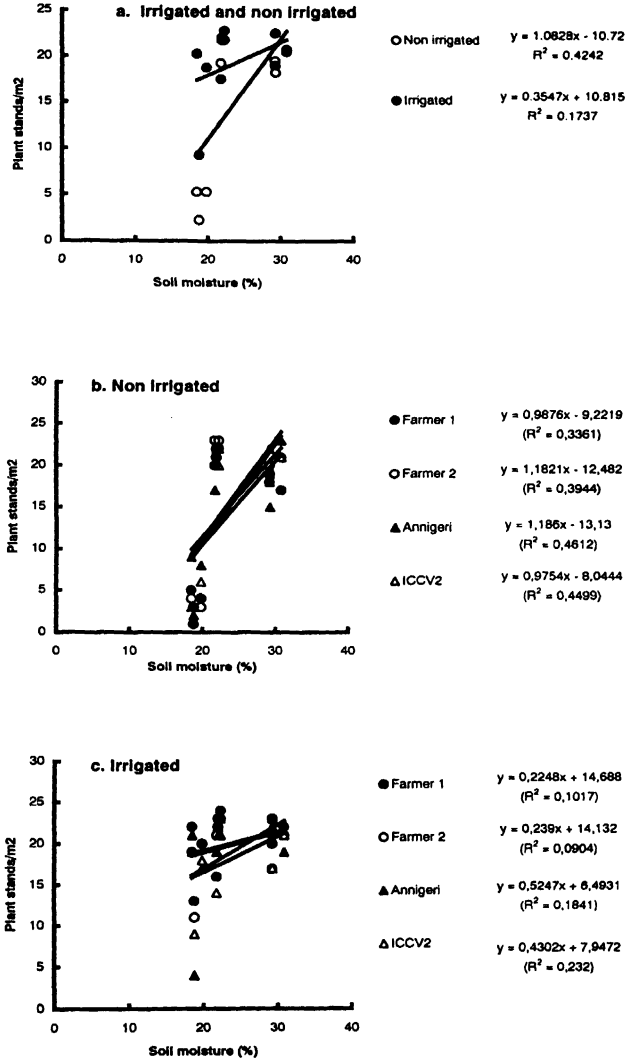


Fig. 9 Regression of soil moisture (%) at 0-10 cm in soil depth in (a) irrigated and non irrigated treatments, (b) non irrigated and (c) irrigated treatments separately on plant stands/m^2 in all the four genotypes

moisture. This shows that in non irrigated or rainfed conditions, soil moisture is an important limitation to establish and sustain targeted plant stand and its ultimate effect on yield.

Genotypic differences in plant stand in field conditions at ICRISAT center were not significant among the four genotypes studied. However, this was a very small set of genotypes and it is dangerous to generalise that genotypic differences were not significant in ability to germinate from suboptimal soil moisture content. This needs to be confirmed using a larger set of genotypes.

In studies on seedling emergence at two levels of soil moisture, 20% and 22%, conducted in glass house, plant stand was drastically reduced at 20%. This soil moisture was much below the critical limits of 23-24% for this Vertisol (Saxena *et al.*, 1983). The severe degree of water stress resulted in complete failure of two genotypes, farmer 2 and ICCV2 (Table 15b). At 22% soil moisture content, the germination percentage ranged between 20-80% for genotypes. The genotype farmer 2 was significantly the most superior.

From the literature it is evident that large seeded varieties give more plant population compared to small seeded ones (Eser *et al.*, 1991). But from our field studies it is clear that there was no significant

difference between large and small seeded varieties regarding plant stand. Such non significant effect of seed size on final plant count was also observed in chickpea by Bhor *et al.*, (1988). The differences, however, became apparent when germination tests were conducted in the glass house (Table 15b) and it was shown through simple correlation studies between seed quality parameters and germination (Table 16). An attempt was also made in the present study to draw relationship between seed size, water uptake and germination in chickpea genotypes. It is obvious from the results that the relationship between rate of water uptake and seed germination was positive (Fig. 10a) but significant only at 10% level (Table 16). Total water uptake and germination % were negatively correlated , but the correlation was not significant at 20% soil moisture content, perhaps because of lesser quantity of water in the soil and its restricted availability, inhibiting imbibition and water uptake (Table 16). This negative correlation became significant at 22% soil moisture content (W/W) because of relatively greater water content and its availability. The negative correlation between germination percentage and total water uptake seems to be because of strong and negative association between hundred seed weight and surface/volume ratio (r = -0.99) and between hundred seed weight and germination percent (r = -0.74). Total water uptake was positively correlated with seed size (r = 0.84), indicating that it is related with the capacity of the seed to accumulate water (Table 16a, Fig.11).

Table 16: Correlation between total uptake, rate of uptake, germination (%) at 20% and 22% soil moisture in glass house and (a) physical seed characteristics and (b) bio-chemical seed characteristics

(a) physical seed characteristics

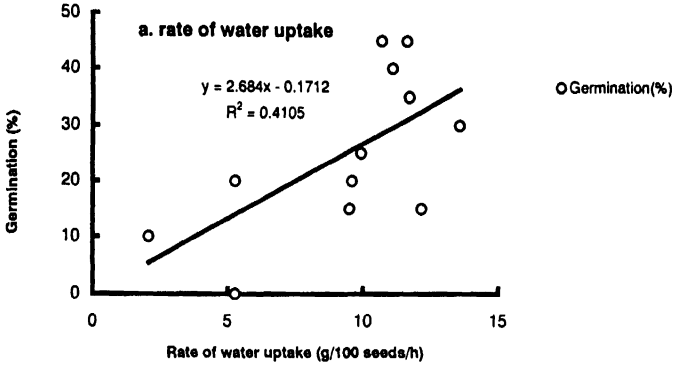
S No.	Parameter	1	2	3	4	5	6	7
1	Total uptake	1.00						
2	Rate of uptake	-0.88	1.00					
3	Hundred seed weight	0.84	-0.81	1.00				
4	Surface area	0.78	-0.75	0.99	1.00			
5	surface to volume ratio	-0.78	0.74	-0.99	-0.99	1.00		
6	Germination (20% moisture level)	-0.287	0.392	-0.321	-0.246	0.23	1.00	
7	Germination (22% moisture level)	-0.603	0.53	-0.737	-0.755	0.77	0.03	1.00

For 10 df at 1 % level --- 0.708
at 5 % level --- 0.576

(b) bio-chemical seed characteristics

S No.	Parameter	1	2	3	4	5	6	7	8	9
1	Total uptake	1.00								
2	Rate of uptake	-0.88	1.00							
3	Hundred seed weight (g)	0.84	-0.81	1						
4	Protein %	0.81	-0.91	0.86	1.00					
5	Oil %	-0.75	0.74	-0.75	-0.68	1.00				
6	Total soluble sugars %	0.83	-0.78	0.86	0.84	-0.88	1.00			
7	Starch %	0.40	-0.37	0.06	0.24	-0.13	0.09	1.00		
8	Germination (20% moisture level)	-0.29	0.39	-0.32	-0.24	0.35	-0.21	-0.10	1	
9	Germination (22% moisture level)	-0.6	0.53	-0.74	-0.44	0.469	-0.461	0.097	0.027	1

For 10 df at 1 % level --- 0.708
at 5 % level --- 0.576



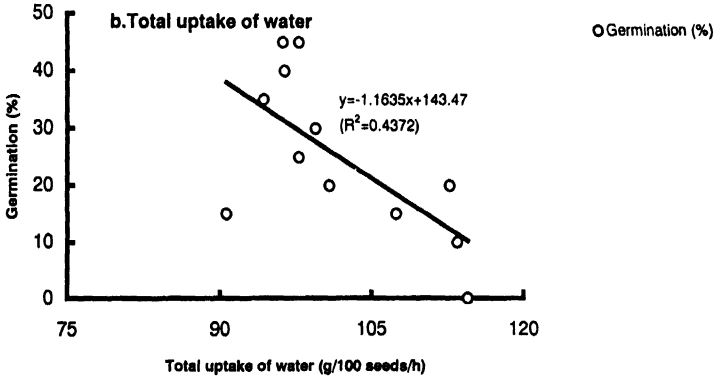


Fig. 10 Regression of germination on(a) rate of water uptake (g/100seeds/h) and (b) Total uptake of water (g/100 seeds).

The negative correlation between hundred seed weight and germination (r = -0.74, Table 16a) shows that, in general, smaller seeds (with lower hundred seed weight) germinate better from suboptimum seed bed moisture (22% soil moisture level). The rate of uptake of water was also rapid in small seeds (r = -0.81 between seed size and rate of uptake, Table 16a, Fig.11). The rapid rate of uptake of water in the small seeds was correlated positively with surface/ volume ratio (r = 0.74 between rate of uptake and surface to volume ratio, Table 16a). Thus, smaller seeds, with a larger surface/volume ratio germinate better from low (22%) soil moisture content (r = 0.77 between surface to volume ratio and germination at 22% soil moisture content, Table 16a).

In the present study the genotypes showed significant difference in biochemical seed traits (Table 15a). Seed size was correlated positively with seed metabolite contents, e.g., TSS, proteins and starch, but negatively with oil content (Table 16b). Since the total uptake of water was correlated positively with seed size, the relationship between total uptake of water and metabolite content, except oil %, became positive. Also, there was strong and negative correlation between total uptake and rate of uptake of water (r= -0.88), which in some way reversed the positive relationship between total uptake and biochemical parameters in to a negative between rate of uptake of water and chemical constituents of the seeds.

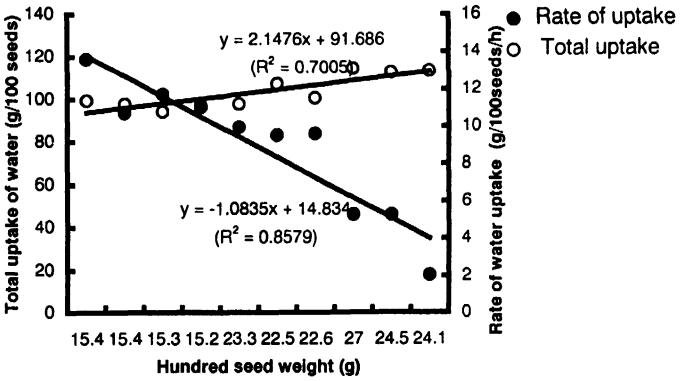


Fig. 11 Regression of total uptake of water(g/100seeds) and rate of water uptake (g/100seeds/h) on hundred seed weight

From the foregoing discussion it is quite clear that surface/volume ratio is the most important seed quality trait, determining rate of water uptake. The rate of water uptake is strongly correlated with germination of seed under conditions of suboptimum seedbed moisture. Calculating surface area by measuring seed diameter with the help of a Vernier Caliper is a tedious procedure. We found that the alternative method of indirect computation of seed diameter by water displacement methods, seem both simple and strongly correlated with seed diameters measured in different directions of seed (Table 17a) and explained 90-98% variation in observed seed diameters (Fig. 12). Similar strong and positive correlation was observed between the two methods of calculating surface/volume ratio (Table 17b).

In the present findings the effect of seed quality on plant stand and their concomitant effect on field performance was also studied. At ICRISAT center, a positive correlation between plant stand and LAI at 40 and 47 DAS as well as with CGR (Table 18) is not surprising because these physiological parameters are a function of number of plants, particularly when plant population is low and un-uniform. However there was no relationship between plant stand and RGR.

The number of branches seems to increase with increasing number of plants/m^2 when water is not limiting as seen in the positive

Table 17: Correlation between (a) measured and computed diameters and (b) surface to volume ratios of seed

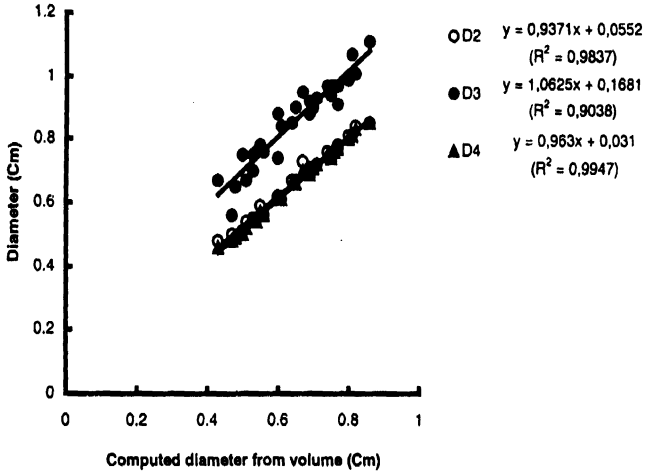
a. Diameters of a seed

	D1	D2	D3	D4	D5	D6
D1	1					
D2	0.96	1				
D3	0.97	0.99	1			
D4	0.93	0.95	0.95	1		
D5	0.97	0.99	0.99	0.95	1	
D6	0.96	0.99	0.99	0.98	0.99	1

b. Surface to volume ratios of a seed

	SAV1	SAV2	SAV3	SAV4	SAV5	SAV6
SAV1	1					
SAV2	0.96	1				
SAV3	0.96	0.99	1			
SAV4	0.89	0.93	0.93	1		
SAV5	0.96	0.99	0.99	0.93	1	
SAV6	0.95	0.99	0.99	0.97	0.99	1

D1: Computed diameter from volume
D2: Measured diameter across the seed
D3: Measured diameter across the seed
D4: Measured diameter across the beak
D5: Average of D2 and D3
D6: Average of D2, D3and D4
SAV1: Surface to volume ratio in case of measured volume
SAV2: Surface to volume ratio computed from D2
SAV3: Surface to volume ratio computed from D3
SAV4: Surface to volume ratio computed from D4
SAV5: Surface to volume ratio computed from D5
SAV6: Surface to volume ratio computed from D6



D2=Diameter measured across the seed
D3=Diameter measured across the seed
D4=Diameter measured across the beak

Fig.12 Regression of computed diameter from volume on measured diameters D2, D3, D4

Table 18: Correlation between plant stands/m2, days to maturity, LAI, CGR, RGR, shoot mass, yield and HI (%

S No.	Parameter	1	2	3	4	5	6	7	9	10	11
1	Plant stand/m2 10DAS	1.00									
2	Plant stand/m2 at harvest	0.94	1.00								
3	Days to maturity	-0.68	-0.63	1.00							
4	LAI 40 DAS	0.76	0.64	-0.61	1.00						
5	LAI 47 DAS	0.74	0.61	-0.35	0.75	1.00					
6	CGR ($g\ m^{-2}\ wk^{-1}$)	0.64	0.50	-0.60	0.59	0.70	1.00				
7	RGR ($g\ g^{-1} day^{-1}$)	0.02	-0.06	0.01	0.14	0.36	0.53	1.00			
9	Shoot mass ($Kg\ ha^{-1}$)	0.88	0.85	-0.50	0.80	0.80	0.61	0.14	1.00		
10	Grain yield ($Kg\ ha^{-1}$)	0.84	0.79	-0.55	0.80	0.82	0.68	0.22	0.97	1.00	
11	HI (%)	0.80	0.75	-0.67	0.72	0.72	0.66	0.10	0.84	0.90	1.00

For 70 df at 1 % --- 0.302
at 5 % --- 0.232

correlation between plant stands/m^2 and number of branches in sow-I and sow-II in both non irrigated as well as irrigated treatments (Fig. 13). In sow-III, where the plant stand was suboptimal, the relationship between plant stands/m^2 and total branches was negative. This suggests when plant stand is suboptimum, the plants use the extra available resources of soil (moisture) and climate (sunlight) and tend to compensate in branch number, the loss in plant stand. This effect was more pronounce in non irrigated treatment of sow III, where it explained nearly 44% variation in branch number (Fig. 13a). This kind of compensation was also observed in the field of farmer-1, where plant stand was poor and the individual plant had occupied a large area compared to the field of farmer-2.

Plant stand was positively correlated with seed yield, shoot mass and HI% (Table 18). In general, plant stand accounted for a large variation in yield ranging from 24-56% variation, particularly in the non irrigated treatment (Fig. 14) compared to the irrigated treatment (Fig. 14). The increase in seed yield with per unit increase in plant stand was more in sow-I compared to sow-II and sow-III, both in the irrigated and non irrigated treatments. Perhaps because the terminal drought and heat conditions were less severe and set later in sow-I which was planted in November compared to sow-III planted in January. Effects of terminal drought and heat are well recognised in chickpea.

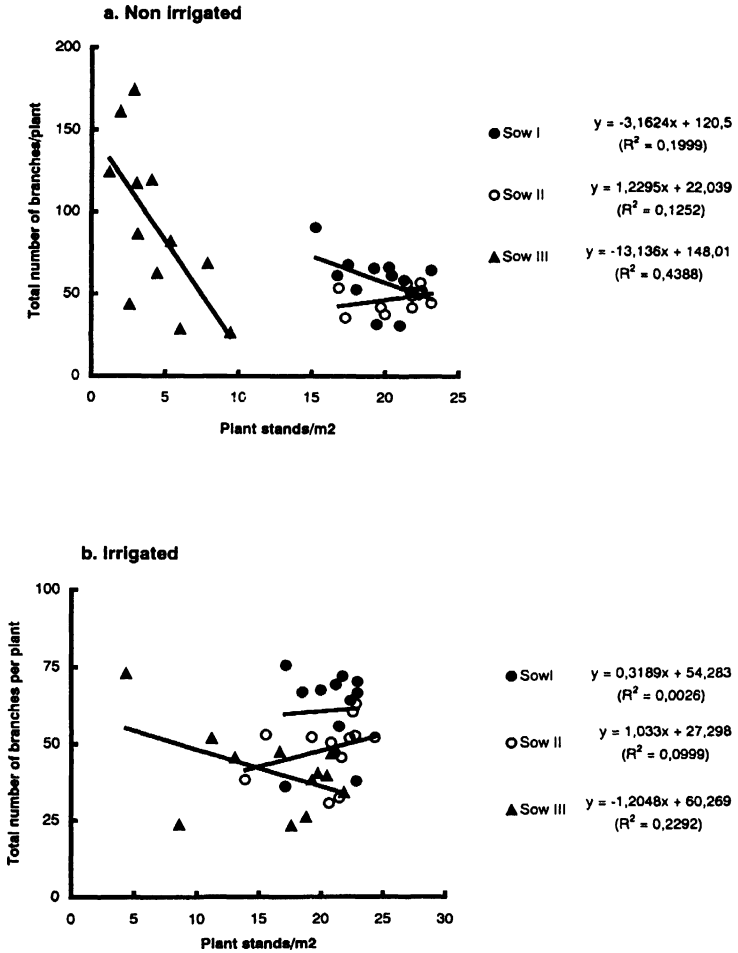


Fig. 13 Regression of total number of branches on plant stands/m2 in (a) non irrigated and (b) irrigated treatments

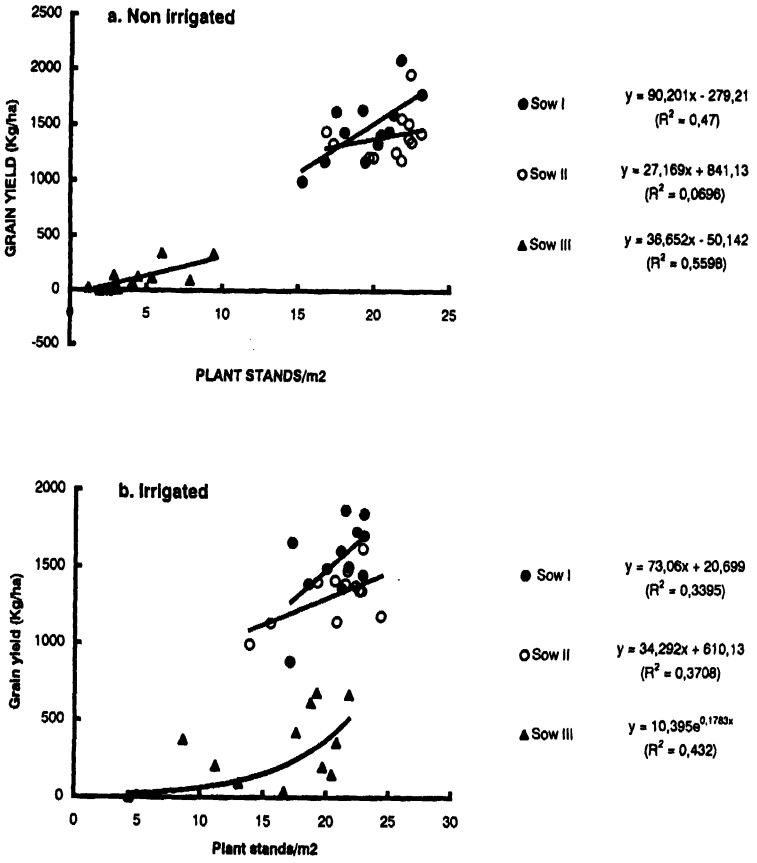


Fig. 14 Regression between plant stands/m^2 and grain yield (Kg ha^{-1}) in (a) non irrigated and (b) irrigated treatments

The effects of low soil moisture in sow-III reflected in lower harvest indices (Table 14). This effect was primarily because a relatively greater decrease in seed yield in sow-III compared to sow-I (95% in non irrigated and 80% in the irrigated treatment; Table 13) than in shoot mass (88% in non irrigated and 63% in the irrigated treatment) (Table 12). Seed yield was very closely correlated with shoot mass ($r = 0.97$, $n=72$) because under drought conditions shoot mass is severly reduced (Table 18).

SUMMARY

CHAPTER VI

SUMMARY

Seed traits related to plant stand establishment were studied in chickpea during Rabi, 1997 at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad and on two farmers fields located at Yelimella village, Rangareddy Dist., A.P.

Ten plots (1m x 1m) were selected randomly in both the farmers fields. In farmer-1 field half of the plots were irrigated and no irrigation was applied in farmer-2 field because it rained seven days after sowing. Soil moisture was determined at the time of sowing and after irrigation/rainfall in order to relate differences in plant stands with soil moisture content in the seed bed.

At ICRISAT center, four genotypes, which differed in seed size, were studied. Two were local cultivars, collected from the two farmers (farmer 1, farmer 2) and the other two varieties (Annigeri, ICCV2) were taken from ICRISAT. Crop was sown on three different dates to create differences in soil moisture at the time of sowing.

In farmers fields plant stands were very poor ranging from 4-17 plants/m^2. Reasons for poor plant stand in farmer-1 field was suboptimum

seed rate, where as in farmer-2 field, inadequate soil moisture and poor seed soil contact due to broad casting method of sowing. Yields were also poor in both the farmers fields.

At ICRISAT center, perfect plant stands were established when soil moisture was adequate as was observed in sow-I and sow-II (20% to 28%). However, the plant stands were reduced drastically when the soil moisture was suboptimum (18-19%.) in the seed bed, as observed in sow-III. Genotypic differences in plant stands and seed yield were not significant in the field experiments conducted at ICRISAT Center.

In the glass house experiment, however, where the soil moisture was below the critical required for germination, plant stands were severely reduced due to soil moisture stress (20% and 22%, w/w). Also, genotypes differed in their ability to germinate and emerge from the soil. Genotype farmer 2 was significantly superior to the other genotypes.

The two genotypes collected from farmers (perhaps land races) were smaller in seed size compared to Annigeri and ICCV2. Farmer 2 genotype had also more surface to volume ratio (which was negatively correlated with seed size) , which might have facilitated a rapid imbibition of soil moisture. Since the smaller seeds require lesser amount of total water

uptake to reach the hydration stage, perhaps they emerge better when soil moisture is inadequate.

Calculating the surface area by measuring the seed diameter with Vernier Caliper is a tedious procedure. It was found that the alternative method of indirect computation of seed diameter by water displacement method seems to be simple and more accurate. Also, the measured diameter with Vernier Caliper and computed by water displacement method were highly correlated.

Seed with more metabolite contents required more time to reach the hydration state. Larger seed had more metabolite content compared to smaller seeds. Hence the smaller seeds require less amount of water to emerge from the limited soil moisture content.

In order to improve plant stand in chickpea, particularly in rainfed situations the following considerations seems very important.

In the four genotypes studied, although the seed size did not show any significant effect in plant stand establishment in field experiments but experiments under controlled glass house conditions with the same four genotypes showed that indeed genotypic differences may be present. This needs to be further investigated in germplasm

selected for a large range of variation in seed size in experiments conducted both in the laboratory and in field.

- Surface to volume ratio seems to be an important quality trait for establishing good plant stands in rainfed conditions. It can be easily selected for on the basis of 100 seed weight, a simple index to follow.

- Need to educate farmers to use optimum seed rate.

- Small seeded varieties will not only give more plants per kg of seed sown, but will be able to germinate and emerge better from inadequate seed bed soil moisture content.

- Ensure sowing time to coincide with optimum seed bed moisture content (depending upon the soil type), which for a Vertisol may be around of 23-24%.

- Essential that the seed soil contact should be proper, particularly when the seeds are sown by broad cast method or even with country seed drill when the soil is light textured.

LITERATURE CITED

LITERATURE CITED

Agrawal P K 1977 Germination, fat acidity and leaching of sugars from the five cultivars of paddy (*Oryza sativa*) seeds during storage. *Seed Science and Technology* 5: 489-498.

Agrawal P K 1979 Genotypic variation in germination and membrane permiability in wheat (*Triticum aestivum*) seeds during storage under ambient conditions. *Seed Research* 7: 120-127.

Agrawal P K 1980 Relative storability of seeds of ten species under ambient conditions. *Seed Research* 8: 94-99.

Agrawal P K and Kharlukhi L 1985 Germination, vigour and leaching of water soluble sugars from seeds of three species during storage under controlled conditions. *Seed Research* 13(1): 99-114.

Aldasoro J J, Matilla A and Nicolas G 1981 Effect of ABA, fusicoccin and thiourea on germination and glucose uptake in chick-pea seeds at different temperatures. *Physiologia Plantarum* 53 : 139-145.

*Asay K H and Johnson D A 1983 Breeding for drought resistance in range grasses. *Iowa State Journal of Research* 57: 441-444.

Auld D L, Bettis B L, Crock J E and Kephart K D 1988 Planting date and temperature effects on germination, emergence and seed yield of chickpea. *Agronomy Journal* 80(6): 909-919.

Bewley J D and Black M 1982 Viability, dormancy and environmental control. In: *Physiology and biochemistry of seeds in relation to germination* Vol. II. Springer-Verlag, Berlin.

Bhor S B, Thete R Y, Patil R B and Bharud R W 1988 Effect of seed size on growth, yield attributes and seed quality of gram. *Seed Research* 16(2): 143-147.

*Biag L D 1986 The extent and significance of seed variation on different cotton (*Gossypium* sp.) varieties. *College* Feb 1986 : 96.

*Bleasdale J K A 1973 Plant physiology in relation to horticulture. The Mac. Millan Press Limited, London, pp.17

Brar G S, Gomez J F, Mc Michael B L, Matches A G and Taylor H M 1991 Germination of twenty forage legumes as influenced by temperature. *Agronomy Journal* 83: 173-175.

Bremner P M, Eckersall R N and Scott R K 1963 The relative importance of embryo size and endosperm size in causing the effect associated with seed in wheat. *Journal of Agricultural Sciences* 61(1): 139-145.

Chastain T G, Ward K J and Wysocki D J 1995 Stand establishment responses of soft white winter wheat to seedbed residue and seed size. *Crop science* 35 (1): 213-218.

*Davis P J 1987 Plant hormones and their role in plant growth and development. Dordrecht/Boston : Nijhoff Publishers.

Dhingra H R, Sureena Chabra, Nirmal Kajal and Varghese T M 1995 Salinity and growth regulators induced changes in seed quality of chick-pea. *Indian Journal of Plant Physiology* 38(4): 322-324.

*Dimalla G G and Van Staden J 1977 The effect of temperature on the germination and endogenous cytokinin levels in peanut. *Zeitschrift fur Planzenphysiol* 82: 274-280.

*Dixit J P, Chourasia S K and Namdeo K N 1992 Influence of existing temperature on seed emergence and vigour index of chickpea planted in different dates. *Crop research* 5 (Supplement): 233-236.

*Duangpatra J and Tongteera V 1986 Peanut seed quality *Kasetsart University Reserch and Development Institute Research Reports* pp. 36-37.

*Dubois M, Gilles K A, Hamilton J K, Rebers P A and Smith F 1956 Colorimetric method for determination of sugars and related substances. *Annals of Chemistry* 28 : 350-356.

Enrique P H and Juan I C 1992 The seed size and its effect on plant establishment, seed yield and seed size harvested in lentil cv. Araucana-INIA. *Agricultura Tecnica* (Chile) 52 (2): 156-161.

Eser D, Ukur A and Adak M S 1991 Effect of seed size on yield and yield components in chickpea. *International Chickpea Newsletter* 25: 13-15

FAO Quarterly bulletin of statistics 1996.

Gallardo M, Delgado M M, Sanchez-Calle I M and Matilla A 1991 Ethylene production and 1-amino-cyclo propane-1-carboxylic acid conjugation in thermo inhibited *Cicer arietinum* L. seeds. *Plant Physiology* 97: 122-127.

*Gepstein S and Ilan I 1980 Evidence for the involvement of cytokinins in the regulation of proteolytic activity in cotyledons of germinating bean. *Plant Cell Physiology* 21: 57-63.

Gupta A K, Jagdeep Singh, Narender Kaur and Rangil Singh 1991 Effect of polyethylene-glycol induced water deficit on germination of chickpea cultivars differing in drought tolerance. *International Chickpea Newsletter* 24: 38-39.

Harrington J F 1972 Seed storage and longevity. In: *Seed biology* Vol. III ed. T.T Kozlowski pp.145-245. Academic Press. New York.

Hernandez-Nistal J, Aldasoro J J, Rodriguez D, Matilla A and Nicolas G 1983 Effect of thiourea on the ionic content and dark fixation of Co_2 in embryonic axes of *Cicer arietinum* seeds. *Physiologia Plantarum* 57: 273-278.

*Heydecker W 1956 Establishment of seedlings in the field: Influence of sowing depth on seedling emergence. *Journal of Horticultural Science* 31: 76-87.

Hoy D J and Gamble E E 1985 The effect of seed size and seed density on germination and vigour in soyabean (*Glycine max* L.) *Canadian Journal of Plant Sciences* 65 (1): 1-8.

*Ilan I and Gepstein S 1981 Hormonal regulation of food reserve breakdown in germinating dicotyledoneous seeds. *Israel Journal of Botony* 29: 193-206.

*Industrial method No. 146/71A 1972 Technicon Industrial Systems/Tarry Town, New York. 10591.

*ISTA 1993 International rules for seed testing. *Seed Science and Technology* 21: 1-288.

Jackson M L 1967 Soil chemical analysis, Prentice hall of India Private Ltd, New Delhi.

Jackson M L 1973 Soil chemical analysis, Oxford IBH Publishing Company, Bombay.

*Jacobson J V, Higgins T J V and Zwar J A 1979 Hormonal control of endosperm function during germination. In: Rubenstein L, Philips R L, Green C E and Gengenbach B G (eds.): *The plant seed development, preservation and germination* pp: 241-262 Academic Press New York ISBN 0-12-602050-7.

*Jordan W R and Miller F R 1980 Genetic variability in sorghum root systems implications for drought tolerance. In: *Adaptation of plants to water and high temperature stress* Turner N C and Kramer P J (eds.) 383-399.

Joseph B and Varma S C 1994 Increasing moisture use efficiency using 'Jalshakthi' in chickpea. *Annals of Agricultural Research* 15(4): 440-444.

Julin-Tegelman A and Pinfield M 1982 Changes in the level of endogeneous cytokinin like substances in *Acer pseudoplatanus* embryos during stratification and germination. *Physiologia Plantarum* 54: 318-322.

Kaul J N and Sekhon H S 1976 Performance of three chickpea (gram) genotypes, as affected by the dates of sowing and row spacing. *Crop improvement* 3: 22-26.

Keatinge J D H and Cooper P J M 1983 Kabuli chickpea as a winter-sown crop in Northern Syria: Moisture relations and crop productivity. *Journal of Agricultural Sciences* (Cambridge) 100: 667-680.

*Khan A A and Tao K L 1978 Phyto hormones, seed dormancy and germination. In: Letham D S, Goodwin P B and Higgins T J V (eds): *Phytohormones and related compounds*. A comprehensive treatise. Vol. II: 371-423.

Kumar V, Singh S, Yadav H D and Yadav A 1992 Effect of physical environment of soil and seeding depth on pearlmillet germination in light textured soil. *Haryana Agricultural University Journal of Research* 22 (3): 180-181.

Lal B M, Rohewal S S, Verma S C and Vedprakash 1963 Chemical composition of some sure strains of bengal gram. *Annals of biochemistry and experimental medicine*. 23: 543-548

*Lee J I, Park H W and Han E D 1985 Effects of seed size and cotyledon removal on germination and yields in peanuts. *Korean Journal of Crop Science* 30 (3): 245-251.

Mian M A R and Nafziger E D 1994 Seed size and water potential effects on germination and seedling growth of winter wheat. *Crop science* 34 (1) 169-171.

Munoz de Rueda P, Gallardo M, Sanchez-Calle I M and Matilla A J 1993 Germination of chickpea seeds in relation to manipulation of the ethylene pathway and polyamine biosynthesis by inhibitors. *Plant Science* 97:
31-37.

Narayanan A, Saxena N P and Sheldrake A K 1981 Varietal differences in seed size and seedling growth of pigeon pea and chick-pea. *Indian Journal of Agricultural Sciences* 51(6): 389-393.

*Official and Tentative Methods of the American Oil Chemists' Society 1981 Third edn. (Ab3-49) American Oil Chemist's Society, 508 South Sixth Street, Champaign, Illinois 61820, USA.

*Olsen S R, Cole C V, Watanabe F S and Deam L A 1954 Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *Circular of United States Department of Agriculture* : 939.

Radford P J 1967 Growth analysis formulation their use and abuse. *Crop Science* 7: 171-175.

*Ragasits I and Lonhardne B E 1992 Effect of wheat seed size on seed value and on yield quantity and quality. *Novenytermeles* (Hungary) 41 (2): 149-153.

Raje R S and Khare D 1996 Effect of seed size on seed yield, seedling vigour and quality attributes of chickpeas. *Indian Journal of Pulses Research* 9(1): 66-67.

Revilla E M, Martin L, Nicolas G, Legaz M E and Villalobos N 1988 Effects of high temperature on the variation and transport of endogenous cytokinins during the germination of chickpea seeds. *Journal of Plant Physiology* 132: 223-228.

Rodriguez D, Matilla A, Aldasoro J J, Hernandez-Nistal J and Nicolas G 1983 Germination of *Cicer arietinum* seeds and thiourea induced phytotoxicity. *Physiologia Plantarum* 57: 267-272.

*Sanchez-Calle I M and Matilla A J 1989 The alteration by abscisic acid of ethylene production in germinating *Phaseolus vulgaris* L. seeds together with the effects of kinetin and the seed coat. *Agr. Med.* 119: 18-26.

*Saxena M C 1980 'Recent advances in chickpea agronomy'. *Proceedings of the international workshop on chickpea improvement*, 28 Feb - 2 Mar 1979, Hyderabad, Andhra Pradesh., India, pp 89-96, ICRISAT. Patancheru, India.

Saxena M C 1984 Agronomic studies on winter chickpeas In: Saxena M C and Singh K B (eds.) *Aschochyta Blight and Winter sowing of chickpeas*. The Hague, Netherlands, Martinus Nizhoff/junk.

Saxena N P 1987a Screening for adaptation to drought: Case studies with chickpea and pigeonpea. In: *adaptation of chickpea and pigeonpea to abiotic stresses* : Proceeding of Consultants Workshop, ICRISAT Patancheru, India, December 1984.

Saxena N P 1987b Screening for adaptation to drought: Case studies with chickpea and pigeonpea. In: *Adaptation of chickpea and pigeonpea to abiotic stresses*: Proceedings of an international workshop 19-21 Dec 1984. ICRISAT centre. India : 63-76.

Saxena N P, Johansen C, Saxena M C and Silim S N 1993 Selection for drought and salinity tolerance in cool-season food legumes In: Singh K B and Saxena M C (eds.) *Breeding for stress tolerance in cool-season food legumes*. ICARDA, Wiley-Sayce Co-publication pp 245-269.

Saxena N P, Kapoor S N and Bisht D S 1983 Emergence of chickpea seedlings in suboptimal seed bed moisture. *International Chickpea Newsletter* 9: 13-14.

Saxena N P, Narayanan A and Sheldrake A R 1981 Effect of seed grading on the yields of chickpea and pigeonpea. *Indian Journal of Agricultural Sciences* 51(10): 699-702.

Saxena N P and Shekdrake A R 1976 *Pulses Physiology Annual Report* 1975-1976 part II: Chickpea physiology ICRISAT, Hyderabad, India: 176

Setia N, Sangeeta, Setia R C and Malik C P 1993 Alterations in growth and yield components of Lentil in response to foliar application of naphthalene acetic acid. *Indian Journal of Plant Physiology* 36: 47-52.

Shahi J P, Singh J, Agrawal I and Lal M S 1986 Studies on variability for seed size, permeability of seed coat to water and germination in lentil (*Lens culinaris*) *LENS-Newsletter* 13 (2) 14-15

*Sharma J 1978 Report of the agronomy section of the pulses improvement project at University of Agriculture Udaypur research station Durgapur, India 1977-78

Singh A R 1987 Effect of seed size on seed viability and seedling vigour in sorghum *Journal of Maharastra Agricultural Universities* 12 (1) 141-142

Singh D, Surender Singh and Rao V U M 1994 Effect of temperature on emergence of seedlings in different chickpea cultivars *Crop Research* 7(3) 489-490

Singh G and Jain S 1982 Effect of some growth regulators on certain biochemical parameters during seed development in chickpea under salinity *Indian Journal of Plant Physiology* 25 169-179

Singh K and Afria B S 1985 Seed germination and seedling growth of chickpea under water stress *Seed Research* 13(2) 1-9

*Singh U and Jambunathan R 1980 Evaluation of rapid methods for the estimation of protein in chickpea (*Cicer arietinum*). *Journal of Food Science and Agriculture* 31: 247-254.

Sivaprasad B and Sharma K S S 1987 Seedling emergence of chickpea (Cicer arietinum L.), pigeonpea (Cajanus cajan L.) and pearl millet (Pennisetam typhoides L.). Effect of differential soil crusting, as induced by raindrop size and depth of sowing. *Plant and Soil* 104(2): 263-268

Smith C W, Wiesner L E, Lockerman and R H Frisbee C 1987 Effect of seed size and temperature on germination index of chickpea (Cicer arietinum L.). *Applied Agricultural Research* 2(5): 342-344

*Smith R C G and Harris H C 1981 Environmental resources and restraints to agricultural production in a mediterranean type environment. In Monteith, J. and Webb, C. (eds.) *Soil water and nitrogen*. The Hague, The Netherlands ; Martinus Nijhoff / junk.

*Southgate D A T 1976 On determination of food and carbohydrates. *Applied Science Publishers Ltd*. London, UK. pp: 52-55.

*Subbiah B V and Asija G L 1956 A rapid procedure for the estimation of available nitrogen in soils. *Current Science* 25: pp 32

*Taylor J S and Warieing P F 1979 The effect of the stratification on the endogeneous levels of gibberellins and cytokinins in seeds of Douglas fir (*Pseudotsuga mensiesii* minb. Franco) and sugar pine (*Pinus lambertiana* Dougl.). *Plant Cell Environment* 2: 165-171.

*Van der Maesen L J G 1972 *Cicer* L., Monogrph of the genus, with special reference to the chickpea (*Cicer arietinum* L.): its ecology and cultivation. Veenman H and Zonen N V Wageningen.

Van der Maesen L J G 1987 Origin, history and taxonomy of chickpea. In: Saxena M C and Singh K B (eds.) *The chickpea*: The Cambrian News Ltd, Aberstwyth pp.11-35

Virmani S M, Sivakumar M V K and Reddy S J 1980 Climatological features of the SAT in relation to the Farming System Research Programme. *Proceedings of International Workshop on the Agroclimatological Research needs of the Semi-Arid Tropics*, ICRISAT, Patancheru, India, November 1978.

Vyas S C and Nene Y L 1984 Note on the influence of storing thiram treated gram (*Cicer arietinum* L.) seed on germination. *Seed Research* 12(1): 107-109.

Waldia R S, Ram C, Sood D R, Punia R C and Chhabra A K 1991 Variation for seed mass, seedling vigour and quality attributes in Desi and Kabuli chickpea genotypes *International Chickpea Newsletter* 24 15-17

*Watson D J 1952 The physiological basis of variation in yield *Advances in Agronomy* 4 101-145

* **Originals not seen**

The references in the literature cited are arranged as per the revised PG Guidelines for thesis presentation, 1980 (as amended upto May, 1997) of Acharya N G Ranga Agricultural University.