INITIAL VIABILITY AND CROP YIELDS IN COWPEA (*Vigna unguiculata* L. Walp)

BY

B. MOHAN KUMAR

A PROJECT REPORT

SUBMITTED TO THE FACULTY OF THE POST-GRADUATE SCHOOL
INDIAN AGRICULTURAL RESEARCH INSTITUTE NEW DELHI
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF

POST GRADUATE DIPLOMA
IN
SEED TECHNOLOGY

DIVISION OF SEED TECHNOLOGY
INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI

1980

Dr. P.K. Agrawal
Senior Scientist

Division of Seed Technology
Indian Agricultural Research Institute
New Delhi-110012

CERTIFICATE

This is to certify that the project report entitled "Initial viability and crop yields in cowpea (*Vigna unguiculata* L. Walp)", submitted in partial fulfilment of the requirements for the Post-Graduate Diploma in Seed Technology of the Post-Graduate School, Indian Agricultural Research Institute, New Delhi, is a record of bona fide research carried out by Shri B. Mohan Kumar under my guidance and supervision. No part of the report has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation has been duly acknowledged.

P.K. [signature] 29.11.80

(P.K. Agrawal)
Advisor

November, 1980.

ACKNOWLEDGEMENTS

I express my deep sense of gratitude and indebtedness to Dr. P.K. Agrawal, Senior Scientist, Division of Seed Technology, Indian Agricultural Research Institute, New Delhi and my advisor, for the help and guidance given in planning and execution of the research programme and the constructive criticism and encouragement throughout the course of the investigation as well as in the preparation of the manuscript.

I am thankful to Dr. [illegible] Siddiqui, Head of the Division of Seed Technology and Dr. [illegible] Banerjee, former Head of the Division and Dr. [illegible] Sinha, Professor of Eminence, Water Technology Centre, Indian Agricultural Research Institute, New Delhi for providing necessary facilities for conducting the research project. Sincere thanks are also due to Dr. Balram Sharma, Scientist, Division of Genetics and Dr. Dharam Singh, Scientist, IARI Regional Station, Karnal for kindly providing the seed material in time.

I am grateful to all the scientists of the Division of Seed Technology and Mr. Inder Sarawah for the help received during the course of this investigation. I also record my sincere thanks to Dr. [illegible] Chaturvedi and Mr. R.L. Agrawal, Scientists of Water Technology Centre, Indian Agricultural Research Institute, for the kind cooperation rendered in the successful completion of the field experiment.

It is my previlege to thank all my friends and colleagues particularly, Mr. [illegible] Rajeevan and Mr. [illegible] Vilaschandran, who helped me during the course of the investigation and preparation of this project report. I am also thankful to Dr. V.K.G. Unnithan, Assistant Professor of Agricultural Statistics, Kerala Agricultural University for his valuable suggestions and help in the statistical analysis of the data.

Thanks are also due to the Kerala Agricultural University for deputing me to undergo this programme.

New Delhi   ([illegible])

November, 19[illegible].

CONTENTS

LIST OF TABLES

... contd.

LIST OF TABLES contd.

LIST OF ILLUSTRATIONS

1. INTRODUCTION

Cowpea (Vigna unguiculata L. Walp) is widely grown in the Asian, African and American continents. In India pulses occupy an area of 23.5 million hectares producing 12.1 million tonnes. It constitutes an easy and readily available source of good quality protein in the diets of millions. Although it has been cultivated for centuries in these regions, the yields are low and unstable. Attempts have been made to improve the yield of cowpea (Sinha, 1974).

Cowpea is grown mostly as a rainfed crop and indeterminate types have been reported to perform better under dryland agriculture (Chaturvedi et al., 1980). However, seeds with reasonable germination percentage at sowing time are not adequately available because the loss of viability of cowpea seeds under ambient conditions of storage is faster than other pulses like green gram (Vigna radiata) (Agrawal, unpublished). Seeds require storage for at least one planting season i.e. from harvest to subsequent sowing which is usually of six months duration. Loss of viability is influenced by many storage factors, but relative humidity and temperature are the two main factors influencing viability of seeds during storage.

Seed deterioration leading to loss of viability as a result of various physiological and biochemical factors can affect the yield of the crop in two ways : first the decreased germination leading to a sub-optimal population of plants per unit area; secondly, the deterioration may result in poor performance by the surviving plants. Theoretically, by increasing seed rates, the first aspect of the problem could be overcome (Abdalla and Roberts, 1969b). However, regarding the second aspect, there exists an information gap.

Hence a field experiment was laid out with the following objectives :

1. to study the effect of loss of seed viability on growth and yield of indeterminate cowpea, and
2. to investigate whether the deleterious effects due to loss of viability could be compensated by increasing the plant population per unit area.

2. REVIEW OF LITERATURE

Seed deterioration leading to loss of viability can affect the yield of the crop in two ways : first the decreased germination can lead to a sub-optimal population of plants per unit area; secondly the deterioration may result in a poor performance by the surviving plants. Providing one is aware of the first problem, theoretically it could be overcome by increasing seed rates (Abdalla and Roberts, 1969b). However, regarding the second aspect of the problem not much is known. There is also crop to crop variation with regard to the loss in viability and field performance relationships. There exists an information lacuna in this sphere. The present position regarding the above problem is reviewed here.

2.1. Accelerated ageing

Accelerated ageing techniques have been widely used in industry to determine the functional life span of various kinds of products (Delouche and Baskin, 1973). By exposing seeds to very adverse levels of temperature and relative humidity the rate of deteriorative processes was greatly increased and in a few days information can be gained on the probable longevity of a seed lot under normal conditions and the storability predicted. Many scientists have appreciated the utility of this technique in evaluating seed vigour and storability (Helmer et al., 1962; Rushing, 1969; Woodstock, 1976; and Tekrony and Egli, 1977).

In the present investigation accelerated ageing technique was utilized as a tool for creating variability in germination percentage of the seed lot. There are two means for this end : firstly keep the seeds under ambient conditions and allow the seed to age (natural ageing). The main defect of this method is that it takes long time to get a reasonable drop in germination. Second method is by subjecting the seeds to accelerated ageing treatments for different lengths of time. This is a rapid, inexpensive and simple method. However, since the treatments are very intense, the ageing processes may not be uniform. Also the pattern of loss in viability will not be similar to that of natural ageing. Harrison (1966) has reported differences between yield and viability loss in rapid ageing and slow ageing (natural) treatments in lettuce.

2.2. Loss of Viability and Crop Yields

As mentioned earlier, sub-optimal population per unit area and the poor performance of the survivors are the main ways by which crop yields are affected by lowered viability of seeds. The problem of reduced plant population is important particularly in those species which are unable to compensate for a reduced density (by tillering) and thus have a population yield curve which shows a relatively sharp yield peak at a particular population density (Willey and Heath, 1969). Cowpea, which can not compensate for a reduced density fall under the above category of crops.

2.2.1. Loss of viability - its effects on the developmental stages of the crop

The final yield may be considered as a measure of the total cumulative growth of the crop. Abdalla and Roberts (1969b) after detailed examination of the root growth in broad beans and peas have reported that the rate of growth is affected if the storage conditions have led to some loss of viability. Reducing viability to 60 per cent or below had significant and relatively large effects on root growth. Further decreases in viability to about 50 per cent had little effect on the root growth of the survivors. However, the initial low growth did not persist.

The increase in dry weight of pea shoots over the first six weeks showed a decrease in mean growth rate of surviving seeds : the growth rate was about 25 per cent less than that of the control plants from seeds which showed 100 per cent viability (Abdalla and Roberts, 1969b).

At later stages, the treatments on beans and peas led to small but highly significant reduction in plant height. The treatments tended to cause marked increase in plant-to-plant variations in plant height. In most cases, these effects of seed storage treatments on plant height were often paralleled by similar decreases in tiller or leaf number and increases in the plant to plant variation in leaf number.

During the period between 5 to 6 and 8½ weeks none of the mean relative growth rates were significantly different from the controls. However, all storage treatments had greater values than the controls. It was concluded that the adverse seed storage treatments cause no diminution in the rate of increase in the linear growth of the shoots during the later stages of growth. In fact, there was some indicating a slight compensatory increase in the linear growth rate at this stage. The differences in plant height was therefore attributed to the effect of seed storage treatments on the early stages of growth (Abdalla and Roberts, 1969b).

The storage treatments which reduced viability to about 50 per cent had no effect on final yield of grain or straw in broad beans, peas and barley. Nevertheless such treatments did affect the early growth of roots and shoots of the plants, some individuals were affected more than others so that the variability of the plants was increased. Eventually these early effects on the rate of growth tended to disappear and there was some possibility of compensatory growth during the later stages of development; thus the early slower rates of growth was of little consequence when it came to final yield unless the deterioration was so severe during storage that it led to a drop in viability to below about 50 per cent (Abdalla and Roberts, 1969b). It was however, expressed that these generalisations apply at least for peas, beans and barley, but judging by the different relationship between viability and final yield, would not hold for any species which behaves like lettuce.

Harrison (1977) observed that the rate of germination was inversely related to the degree of deterioration in barley. However, the growth rates were not significantly different.

Perry and Harrison (1977) also in the case of barley reported a lower field emergence in the case of deteriorated seeds lots under unfavourable conditions. Similar lower emergence was also reported by Woodstock et al. (1970) and Agrawal and Singh (1975) in the case of soybeans.

2.2.2. Loss of viability and final yields

The loss in crop yields due to decreased viability could theoretically by overcome by increasing the seed rate. But even if we compensate for this potential loss of yield by increasing the seed rate, there is also evidence that, in many cases, the yield of plants produced from surviving seeds decreased with age of the seed e.g. in wheat and Brassica (Cruciani, 1934) and in maize (Dungan and Koehler, 1944).

There have been a number of investigations in which reduced yields were reported from old seeds, in other reports no effect of age was found and exceptionally in mung (Vigna radiata), Rodrigo (1939) observed significantly higher yields from old seeds. It was considered that the seed requires quite certain seasoning or curing before it is capable of attaining the peak of its viability. Barton and Garman (1946) working on six horticultural species did not observe any significant reductions in yield with increasing chronological age of the seed except in the case of tomato. Barton (1961) referring to tomato suggested that the actual age of the seed is of much less importance than the environment in which it is kept. Brown (1962) also observed no significant difference in yield of the several ages of oat seeds.

On the other hand, Chirkovskii (1953) reported reduced yields of leaves per plant from old tobacco seeds.

Harrison (1966) carried out two types of experiments on lettuce, in the first, 'slow ageing' treatments were used in which the seeds were stored for 5 to 10 years in open storage or sealed in air or carbon dioxide at 18°C, in the second type of trials he employed 'rapid ageing' treatments in which the seeds were stored at 10 per cent moisture content at 35°C for 8 to 11 days.

In rapid ageing treatments significant decreases in growth were only obtained once viability had dropped below about 50 per cent. It also showed roughly the same relationship between percentage viability and yield derived from the surviving seeds. In the slow ageing treatments, the results again indicated a consistent relationship between loss of viability and yield irrespective of the cultivar or ageing treatment, but the relationship was distinctly different from that shown by rapid ageing treatments. In this treatment even a small loss of viability resulted in a severe loss of yield in plants derived from the surviving seeds.

The reason for the two distinct types of relationship between loss of viability and yield was not clear, but there may be two possibilities. First it is possible that conditions leading to a rapid loss of viability produce a different relationship from those resulting in a slow loss of viability; or alternatively the relationship between loss of viability and dry weight of seedlings may be different from that between loss of viability and final yield.

The results of the experiment conducted by Harrison (1966) on onion seeds which was 5 years old and had been stored at 18°C for 4 years sealed in various gases showed a decrease in yield with loss of viability.

Field trials conducted by Ching and Calhoun (1968) clearly indicated that seed production and forage yield were not significantly different in seed lots having different germinabilities ranging from 97 to 79 per cent.

Abdalla and Roberts (1969a) reported that in peas, broad beans and barley, percentage viability appeared to be a reliable index of the deterioration of the surviving seed as indicated by the accumulation of chromosome aberrations. A field experiment was conducted with a view to find out whether percentage viability would also indicate the growth potential of the surviving seeds under field conditions (Abdalla and Roberts, 1969b). There was three storage treatments applied to the three species so that they lost 50 per cent viability and the final economic yields were compared with control treatments in which there had been no loss of viability. The ageing treatments were as follows : Peas : 25°C, 18 per cent moisture content (m.c.) for 100 days (54 per cent viability); 35°C, 18.0 per cent m.c. for 24 days (53 per cent viability); 45°C, 12.3 per cent m.c. for 17 days (53 per cent viability); beans : 25°C, 18.5 per cent m.c. for 45 days (48 per cent viability); 35°C, 18.5 per cent m.c. for 17 days (43 per cent viability); 45°C, 11.5 per cent m.c. for 37 days (53 per cent viability); barley : 25°C, 18 per cent m.c. for 54 days (50 per cent viability); 35°C, 18.0 per cent m.c. for 48 days (48 per cent viability); 45°C, 12.1 per cent m.c. for 17 days (47 per cent viability). In all the species the treatments included different rates of ageing and treatments in which a high temperature was combined with a low moisture content or a low temperature was combined with a high moisture content. There were no significant difference between the treatments and the controls for either weight of seeds or weight of straw.

A field trial was conducted by the above authors on these three species with the following objectives - (1) to confirm that deterioration associated with a reduction of viability to 50 per cent has no significant effect on final yield, (2) to find out whether seed deterioration associated with a reduction of viability below 50 per cent affects final yield and if it does, (3) to find out whether the particular combination of environmental factors during storage or rate of loss of viability is important in determining yield, or whether percentage viability is alone sufficient as an index of yield potentiality.

It was confirmed that seed deterioration associated with a reduction of viability down to 50 per cent had no significant effect on final yield. However, there was evidently a trend of decreasing yield with decreasing viability, but the slope of the curve was gradual so that significant reductions in yield only became evident when viability had dropped to below 50 per cent. There was also a close similarity between the contrasting seed-storage environments in their effect on yield. They also have concluded that percentage viability was an excellent index of the loss of yield potential of the surviving seeds. It was also reported that it was unimportant which factor - temperature or moisture content was responsible for the deterioration, or how rapidly the deterioration has occurred, but only the extent of deterioration was important.

Roberts (1972) has expressed the views that although a simple germination test can act as an index of the potential yield of the surviving seeds, the relationship between viability and yields may be different in different species. On the one hand there is the type of relationship shown by peas, beans, barley and onion in which a significant loss of final yield only occurs when a considerable loss of viability has taken place. On the other hand, there is the type of relationship shown in lettuce in which there is a considerable loss of yield when a small loss of viability has taken place. In the storage of seeds for crop production some loss of viability can be tolerated in the first type, but not in the second. Therefore, from the practical point of view, it is very important to know which category a species belongs.

Harrison (1977) reported that seed deterioration had no significant effect on grain yield in barley. However, plants from deteriorated seeds started to tiller later than controls, but tillering rates were similar.

Various possible explanations for the decreased growth rates in plants from seed populations which have lost viability were advanced by various workers. They are discussed below.

Loss of viability was associated with an accumulation of chromosome damage in the surviving seeds (Abdalla and Roberts, 1968). Cytological examinations have shown that the visible aberrations produced as a result of poor storage conditions rapidly disappear during the growth of the seedlings. It was reported that all visible aberrations in pea roots were no longer present in the meristem when the roots were 10 cm long. This loss of viability of the aberrant cells after division may be because the daughter cells will tend to contain gross deletions and other forms of genetic imbalance. On the other hand minor chromosome damages will persist not only to the maturity of the plant but through to successive generations. The chromosome damage of the intermediate nature may also be selected out during cell division, but it may take longer to disappear than the more obvious aberrations (Abdalla and Roberts, 1969a). He also hypothesized that reduction in growth rate is due to chromosome disturbances of intermediate severity and these may tend to disappear with time so that growth rate eventually returns to normal. This also can provide a satisfactory explanation to the increased plant-to-plant variation as a result of seed deterioration during storage. However, it fails to offer any explanation as to how there is compensation for growth in later stages.

This also ignores the possibility that the lower growth rates found in plants derived from aged seeds could be due to the malfunction of some of the cytoplasmic organelles. Damage to the cytoplasmic organelles persists during the development of the plant though, as with chromosome damage, there would probably be a tendency for the damaged organelles or the cells containing them to be selected out during development. Furthermore, there is evidence that repair mechanisms can operate provided the initial damage was not too great. Consequently the observed gradual return to normal growth rates in plants derived from aged seeds would also be compatible with the hypothesis that the loss of early vigour is due to damage to cytoplasmic organelles (Roberts, 1972).

The practical implication of decreased growth rates for crop production were also discussed by Roberts (1972). According to him, small losses in viability in crops like peas, broad beans, barley and onion are not critical, but because of the lower rates of early growth, the crop will probably be more susceptible to adverse conditions during the emergence and early establishment. For example, such a crop might be expected to be more susceptible for soil-capping, pests, diseases and weed competition. However, under favourable conditions, the decreased early growth rates will have little effect on final yield. In contrast, in crops like lettuce even a small loss of viability apparently indicates a degree of deterioration which will seriously affect the final yield of the crop. According to him in all cases any crop which has been derived from a seed stock which had lost a significant amount of viability should not be used for producing further seed since the evidence indicate that such seed would contain a large amount of genetic mutations. He also pointed out that, in some crops at least, if seedlings are not actually lost during early growth, the early effects of vigour tend to disappear during growth and thus final result may not be quite so catastroptic as indicated by a vigour test. Thus it can not be assumed automatically that a decrease in seedling vigour will lead to a loss of final yield because there are many processes intervening between seedling, vigour and yield (Sinha and Khanna, 1975) and very little information with respect to these intervening processes are available.

3. MATERIALS AND METHODS

The investigation was undertaken at the Division of Seed Technology, Indian Agricultural Research Institute, New Delhi.

3.1. MATERIALS

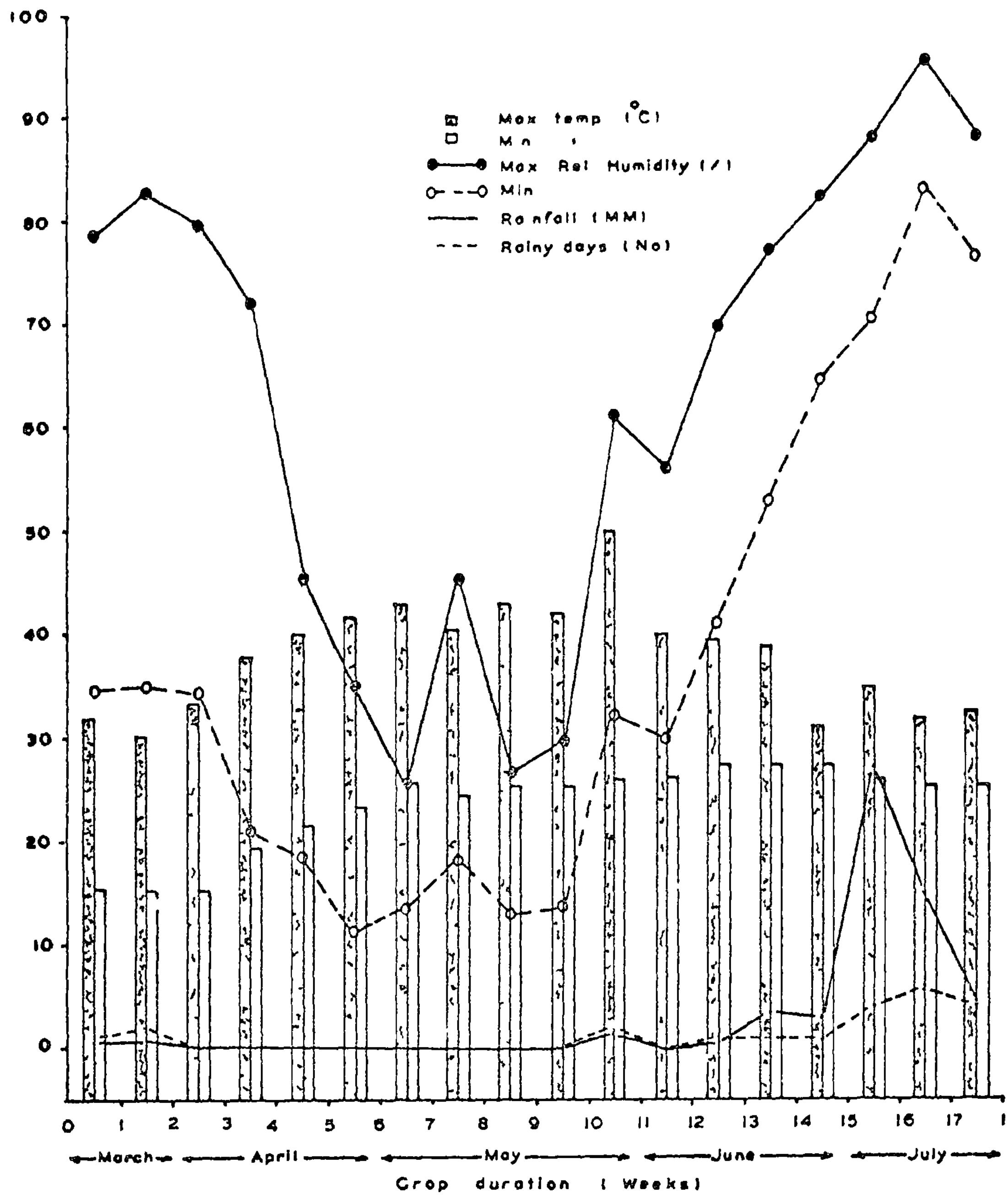
3.1.1. Seeds

Seeds of the cowpea strain 26-4-1 was obtained from Mr. Charan Singh, I.A.R.I. Regional Station, Karnal. It is a semi-erect, indeterminate type which gives two distinct flushes of pods. The strain is characterised with active vegetative growth even after the maturity of the pods. Under conditions of continuous irrigation the variety is observed to have an extended reproductive phase. In the present study also, the variety showed extended flowering and continued vegetative growth till 122 days after sowing when the experiment was terminated.

3.1.2. Climate and Soil

The details of the meteorological observations for the period are presented in Fig. 1 and Appendix I. The soil of the experimental site was a sandy clay loam with high clay and silt content.

Fig 1 Meteorological data for the period from Mar to July 1980



3.1.3. Fertilizers

The fertilizers, urea (45 % N), superphosphate (16 % P_2O_5) and muriate of potash (60 % K_2O) were applied basally to supply 20, 40 and 10 kg/ha of N, P_2O_5 and K_2O, respectively.

3.2. METHODS

3.2.1. Accelerated ageing

Since no information on the loss of viability during accelerated ageing treatment of cowpea seeds was available, an experiment was planned, the details of which are presented below.

3.2.1.1. Incubation of seeds at 80 per cent relative humidity (RH) at 40°C for 28 days :

Seeds kept in a wire basket in single layer was placed in a desiccator containing KCl solution so as to maintain an approximate RH of 80 per cent (Solomon, 1951). The desiccator was then placed in an incubator at 40 ± 1°C for 28 days. Seed germination, moisture, length of roots and shoots, their dry weights and viability by tetrazolium salt were determined at periodic intervals.

Since it took a long time to obtain a reasonable drop in germination capacity, a modified method was adopted, 3.2.1.2. Modified accelerated ageing technique : The seeds were conditioned to the higher moisture status of approximately 26 per cent from 7.45 per cent by adding water at the rate of 18.55 ml per 100 g of seeds. The seeds were taken in thick polythene bags of approximately 800 gauge and water was applied in 3-4 instalments. After each addition, the bags were stapled, seeds thoroughly mixed and kept in a refrigerator at about 5°C to attain the equilibrium moisture level. The final moisture content was estimated and the seeds were transferred either to 40°C or 33°C for varying periods as described below.

After conditioning, a portion of the seed was kept at 33°C for one day (g_2); another portion at 40°C for the first two days and subsequently at 33°C for another two days (g_3). A third lot was kept at 40°C for the first two days and at 33°C for the next four days (g_4). After the treatment all seed lots were transferred to a refrigerator and stored their until sowing. This period ranged from three to eight days depending upon the treatments.

Moisture estimation and germination testing were done before sowing and the figures were taken as treatment levels (see later).

3.2.1.3. Observations taken : The various observations taken at periodic intervals are listed below.

1. Moisture estimation : Moisture content of the seed samples was determined by drying samples in duplicate at 110 ± 1°C for 17 h and was expressed on wet weight basis.

2. Germination testing : Two replicates of 50 seeds each were germinated at 32°C for four days using between paper method (Chalam et al., 1967). The seeds were categorised in to normal, abnormal, dead and hard. The germination percentage was expressed on the basis of normal seedlings only.

3. Viability test : Seeds were preconditioned by soaking at room temperature for 17 ± 1 h and removing the seed coats. Preconditioned seeds were soaked in 0.5 per cent aqueous solution of 2, 3, 5-triphenyl tetrazolium chloride and incubated at 30°C for about 4 h. After the expiry of this period, the solution was drained off and the seeds were washed thoroughly in tap water. The seeds were classified into germinable and non-germinable depending on the staining patterns.

4. Root and shoot length : Ten normal seedlings from each replication were randomly selected and their root and shoot lengths measured and the mean of the two replicates worked out.

5. Dry weight of root and shoot : The above 10 seedlings were separated into root and shoot and then dried at 110 ± 1°C for 17 h. The mean dry weights of root and shoot were calculated per seedling.

3.2.2. Field Experiment

3.2.2.1. Layout : The experiment was conducted during the period from March and July, 1980. It was laid out in a factorial randomised block design with three replications. The allocation of various treatments to different plots was done by randomisation using Fisher and Yates Random Tables (Panse and Sukhatme, 1957). The details of the layout plan are given below :

Total experimental area	: 200 m^2
Plot size	: 5 x 1 m
Number of treatments	: 4 x 2 = 8
Number of replications	: 3
Number of plots	: 8 x 3 = 24

3.2.2.2. Seed material and levels of germination : Seeds with varying germination percentage, the details of which are given in Table 1, was obtained by giving accelerated ageing treatment which has been described earlier. The control (G_1) was untreated seeds with no ageing treatment. All seed lots were treated with Thiram at the rate of 1 g per kg of seeds prior to sowing.

5. Leaf, stem and pod dry weight : The leaves, stem and pods from the five random plants were dried separately 110 ± 1°C for 17 h and the weight recorded.

6. Total dry weight : The various components such as leaf dry weight, stem dry weight and pod dry weight were added to obtain the total dry weight.

7. Date of flowering : The number of days taken for the first flower appearance and the attainment of 50 per cent plant flowering was recorded.

8. Number of pods per plant : The total number of pods from the five randomly selected plants, used for determining total dry weight, were counted and their mean calculated.

9. Length of pods : Ten pods selected at random from each treatment were used for measuring the pod length.

10. Number of seeds per pod : Pods used for measuring the length were used for counting the number of seeds per pod.

11. Dry weight of grains per 10 pods : The grains from the above 10 pods were dried at 110 ± 1°C for 17 h and weighed.

12. Dry weight of husk per 10 pods : The husk from the above 10 pods were dried at 110 ± 1°C for 17 h and weighed.

13. Nitrogen content of plant samples : The total nitrogen was estimated by the indophenol blue method (Novozamsky et al., 1974), the details of which are mentioned below.

Reagents

Alkaline phenolate solution : 20 g of phenol was dissolved in 250 ml of NaOH 1 M and made upto 1 litre.

Sodium nitroprusside : 0.05 per cent.

Disodium EDTA solution : 4 per cent.

Phosphate buffer solution : 13.35 g of $Na_2HPO_4.2H_2O$ was dissolved and to this 50 ml of 1 M NaOH was added and made up to 1 litre. The pH was adjusted to 12 ± 0.2.

Sodium hypochlorite solution : 20 ml of sodium hypochlorite solution was diluted to 100 ml.

Mixed reagent 1 : 100 ml of alkaline phenolate solution was mixed with 200 ml of sodium nitroprusside solution to which 10 ml of the EDTA solution was added.

170084

Mixed reagent II : 400 ml of phosphate buffer was mixed with 100 ml of sodium hypochlorite solution.

Diluted sulphuric acid : 100 ml H_2SO_4 (sp. gr. 1.84) was added to 18 ml of distilled water.

Acid mixture : 6 g of salicylic acid was dissolved in diluted sulphuric acid and made up the final volume to 110 ml.

Hydrogen peroxide : 30 per cent.

Procedure

Digestion : 0.3 g of air dry, finely ground plant material was weighed into a 50 ml volumetric flask. To this, 3.3 ml of acid mixture was added, mixed well and left for 1 h, for the nitration reaction to proceed. 3.3 ml of the acid mixture was used as blank.

The flasks were heated moderately on a hot plate and swirled gently now and then to minimise foaming. Waited for 60 minutes, then at 10 minute intervals 5 drops of hydrogen peroxide were added. The temperature was raised to about 280°C. This procedure was repeated until the resulting solution was clear after 10 minutes at 280°C.

The flasks were cooled and made upto the mark with distilled water. The solution was then filtered.

Analysis : The aliquots of digest and standard series were diluted 1 + 9 with distilled water. 0.2 ml of these diluted solutions were taken to which 3.0 ml of mixed reagent I and 5 ml of mixed reagent II was added and mixed well. Optical density was measured at 630 nm using a Spectronic 20 colorimeter after 90 minutes. The standard curve was prepared from solutions containing 1.2, 2.4, 3.6, 4.8 and 6.00 ppm of nitrogen.

14. Total uptake of nitrogen : This was calculated from the total nitrogen content of the plant and the dry weight of stem, leaves and pods.

15. Relative growth rate : RGR was calculated using the formula $r = 1/t (\log W_t - \log W_0)$ where r = relative growth rate; W = plant weight and t = time (as quoted by Donald, 1963).

3.2.3. Statistical analysis

The data relating to each character was analysed by applying the analysis of variance technique as suggested by Snedecor and Cochran (1967).

4. EXPERIMENTAL RESULTS

4.1.1. Accelerated ageing

The data on the effect of the accelerated ageing treatment (80 per cent relative humidity at 40°C) are presented in Table 2 and Fig. 2.

A perusal of the data indicate that seed moisture content increased with increase in the number of days of treatment. The initial seed moisture content of 7.68 per cent increased to 14.00 per cent after 28 days of treatment. The moisture content increased during the first two weeks of treatment and later no increase in it was observed.

During accelerated ageing treatment no decrease in germination percentage was observed upto 7 days of treatment. Later the germination percentage declined. The rate of fall in germination was maximum between 2nd and 3rd week after treatment. After four weeks of treatment only 28 per cent germination was obtained.

The viability percentage as obtained in tetrazolium test was very close to the germination percentage throughout. The root and shoot lengths and their dry weights did

Fig 2 Effect of accelerated ageing (80% RH at 40°C) on seed germination (%) viability (%) moisture content (%) shoot & root lengths (cm) and their dry weights (g)

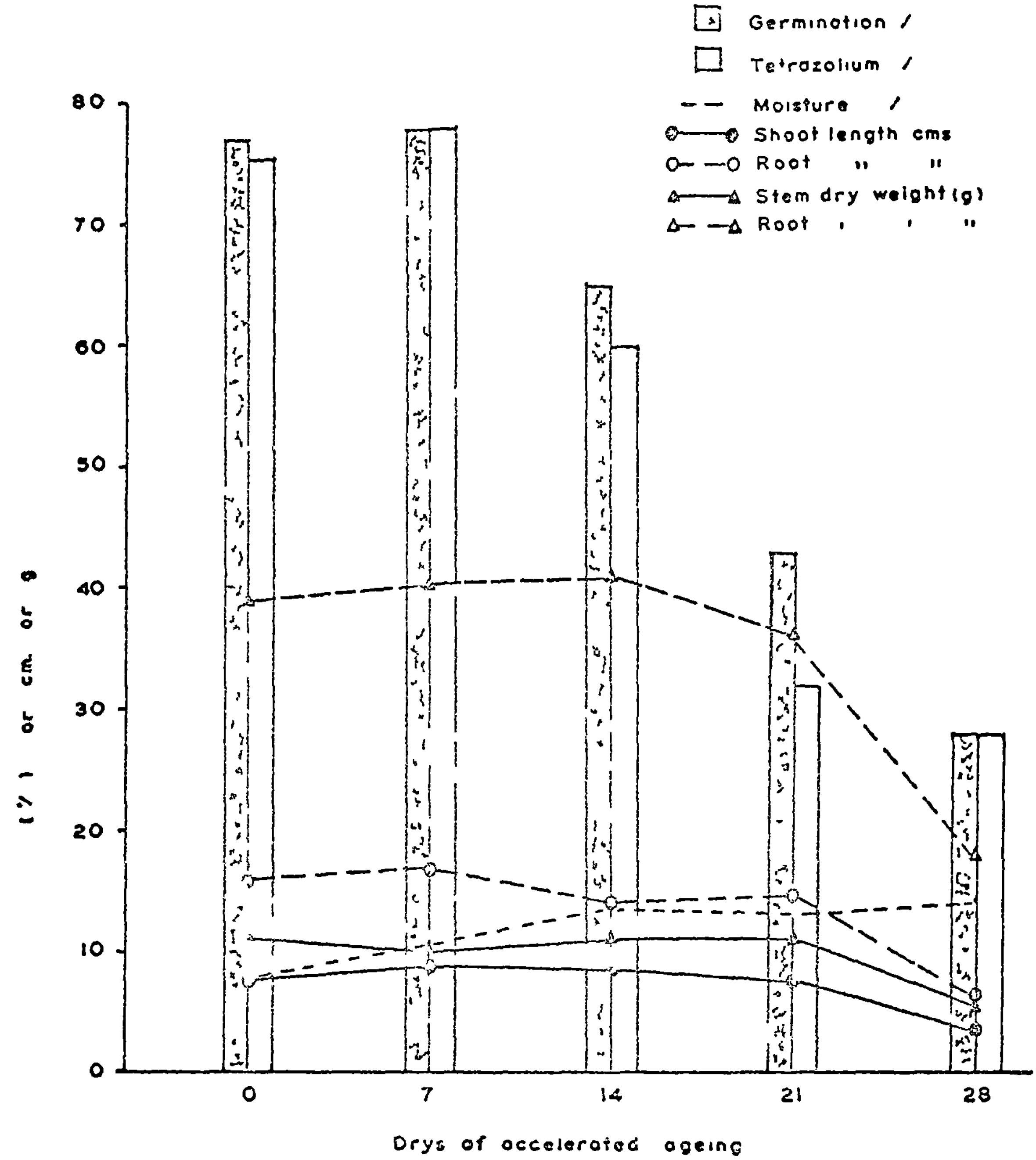
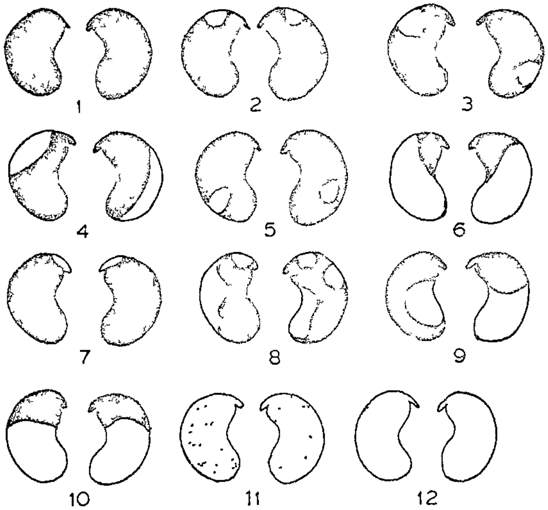


Table 2. Effect of accelerated ageing (80 per cent RH at 40°C) on moisture content, seed germination, viability, shoot length, root length and their dry weight.

No. of days	Moisture (%)	Germination (%)	Tetrazolium (%)	Root length (cm)	Shoot length (cm)	Root dry weight (mg)	Shoot dry weight (mg)
0	7.68	77	75.5	15.78	7.59	10.7	38.5
7	10.84	78	78	16.55	8.83	10.2	40.3
14	13.91	65	60	14.04	6.34	10.7	41.0
21	12.85	43	32	14.34	7.48	11.0	36.1
28	14.0	28	28	6.43	3.27	6.5	18.2

Fig.3 Criteria for interpreting Tetrazolium test results on Cowpea seeds



not change much upto three weeks of treatment. However, after four weeks of treatments, the decrease was considerable.

4.1.2. Tetrazolium Evaluation Group

Based on the staining patterns obtained in the rapid viability test (tetrazolium) the seeds were classified into germinable and non-germinable. The staining patterns and the basis of classifying seeds into germinable and non-germinable are presented in Fig. 3.

4.2. Field Experiment

4.2.1. Field Emergence

The data are presented in Table 3 and Fig. 4 and 5. The effect of different germination levels on field emergence was found to be significant on all days of observation. Germination rate was relatively slow in the control (g_1) but there was a sharp increase after 12 days and a maximum of 50.6 per cent field emergence was obtained at 18 days after sowing. The seed lot possessing 63 per cent germination (g_2) maintained the highest field emergence till 12th day after sowing. This early faster germination has, however, declined at final observation. At the initial stages it was significantly superior to all other

Fig 4 Effect of germination levels on the rate of emergence

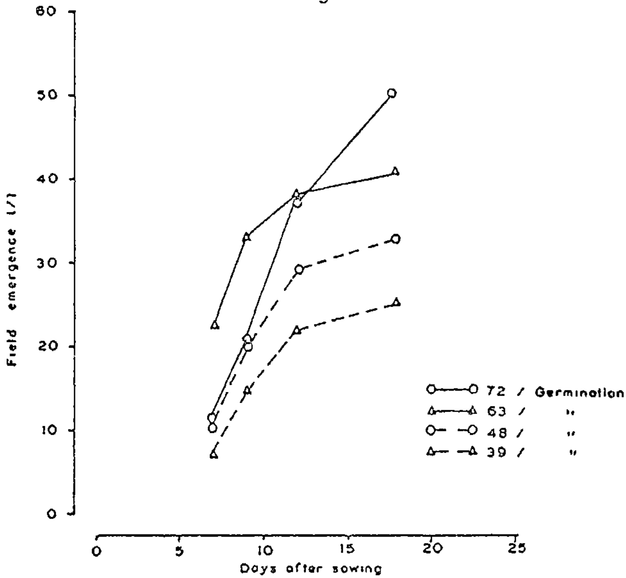


Fig 5 Effect of initial germination levels on field emergence after 18 days of sowing

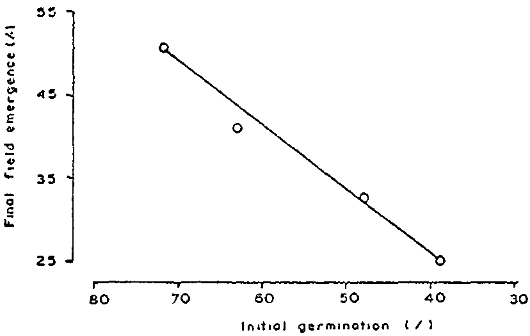


Table 3. Effect of germination levels on field emergence.

Germination level	Days after sowing			
	7	9	12	18
g_1	19.85 (11.5)	27.18 (20.9)	37.49 (37.1)	45.34 (50.6)
g_2	28.30 (22.5)	35.07 (33.0)	38.27 (38.4)	39.84 (41.0)
g_3	18.50 (10.1)	26.67 (20.1)	32.76 (29.3)	34.73 (32.5)
g_4	15.46 (7.1)	22.55 (14.7)	27.75 (21.7)	29.98 (25.0)
L.S.D. (0.05)	8.32	5.76	5.87	4.79
S.E./plot ±	6.76	4.68	3.14	3.09

Figures in parentheses indicate percentages.

treatments. Reducing viability levels to further down adversely affected the field emergence. The effect of 48 and 39 per cent germination levels were on par on 7, 9 and 18th day after sowing.

Observations indicated that the rate of emergence was inversely related to the degree of deterioration (Fig. 5).

4.2.2. Leaf Area

The results are shown in Table 4 and 5 and Fig. 6. Leaf area increased with time in all treatments except for the 39 per cent germination level at the final stage. At 10 days after sowing, maximum leaf area was observed in 39 per cent germination level which was significantly superior to control. However, there was no significant difference between control and the other deterioration levels. The germination levels 63 and 48 per cent were superior to the remaining levels at 15 days after sowing. The various treatments did not exert any significant influence on leaf enlargement during the periods 20, 26 and 45 days after sowing. However, at later stages the differences were significant.

At 103 days after sowing the differences between the two population densities were significant. The table indicates the clear superiority of the low plant population

Fig 6 Effect of germination levels and plant population on leaf area (cm^2) per plant

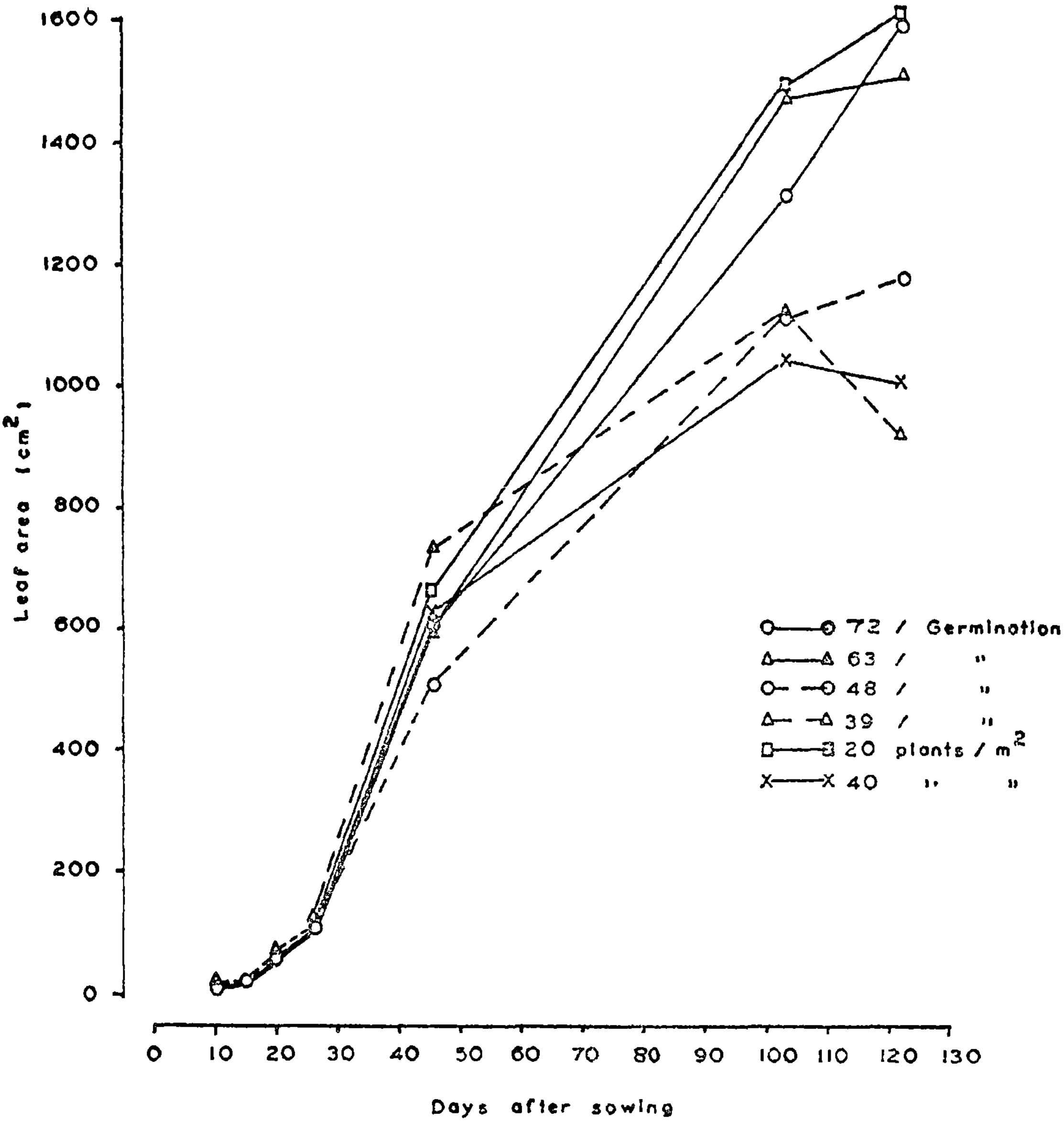


Table 4. Effect of germination levels on leaf area (cm^2) per plant till 20th day of sowing.

Germination level	Days after sowing		
	10	15	20
g_1	14.99	16.01	51.36
g_2	15.35	20.58	57.32
g_3	15.35	19.97	59.97
g_4	16.66	18.40	60.37
C.D. (0.05)	1.42	1.18	-
S.E/plot ±	0.93	1.49	10.62

in terms of leaf area per plant.

At the final phase of crop growth, the effect of germination and plant population were distinctly visible. The control alongwith 63 per cent germination were significantly superior to the other germination levels. There was a gradual decline in leaf area with increasing seed deterioration. The dominant role of plant population on leaf area can be easily made out from the data. The interaction effects were non-significant.

4.2.3. Leaf dry weight

The data are presented in Table 6 and 7 and in Fig. 7. It is seen that mean values of leaf dry weight at various germination levels followed essentially the same trend as

Table 5. Effect of germination levels and plant population on leaf area (cm^2) per plant.

Population / Germination level	Days after sowing											
	26			45			103			122		
	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
g_1	117.41	114.46	115.93	697.55	675.94	686.75	1551.16	1067.39	1309.78	1975.54	1235.74	1585.67
g_2	113.91	128.41	121.16	526.67	650.61	593.64	1024.09	1113.52	1471.31	1819.11	1191.84	1505.48
g_3	134.47	92.63	113.55	471.15	549.36	510.25	1170.54	1059.40	1114.50	1379.53	974.45	1177.01
g_4	126.11	115.69	120.89	398.31	576.08	737.21	1391.85	925.74	1115.80	1214.30	616.00	915.15
Mean	122.98	112.79		648.46	612.96		1485.66	1041.52		1597.13	1004.51	
L.S.D. (0.05)		-			-		For marginal means of p = 308.5			For marginal means of p = 181.71 of g = 256.90		
SE/plot ±		32.49			267.91			352.29			207.50	

Fig 7 Effect of levels of germination and plant population on leaf dry weight (g) per plant

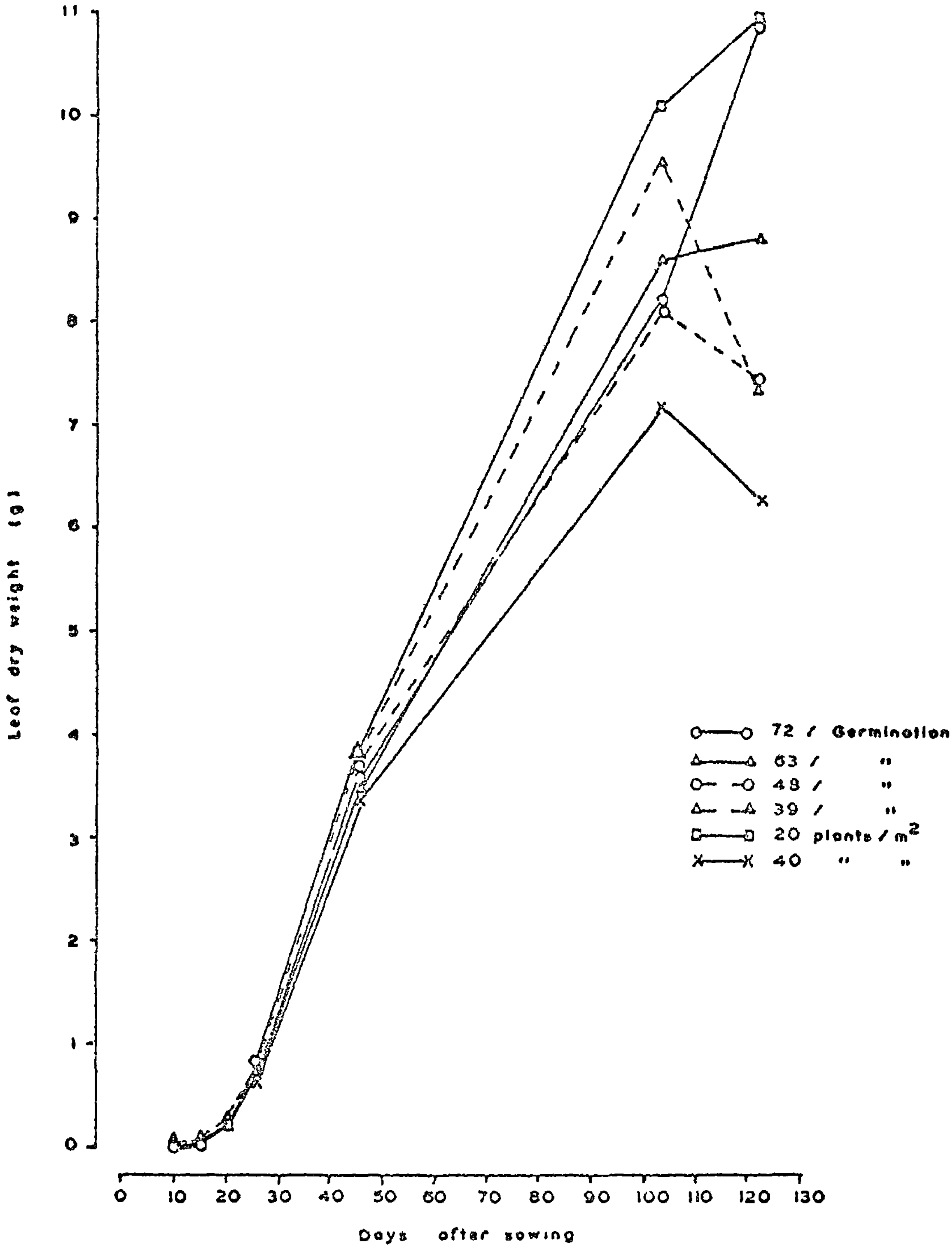


Table 6. Effect of germination levels on dry weight (mg) of leaves per plant (upto 20 days after sowing).

Germination level	Days after sowing		
	10	15	20
g_1	55.07	64.40	247.50
g_2	53.26	65.67	218.40
g_3	55.68	80.19	245.90
g_4	61.47	75.23	211.00
C.D. (0.05)	4.46	5.73	-
SE/plot ±	5.62	4.66	35.70

that of leaf area upto 15 days after sowing. The variation among germination levels were not statistically prominent at 20, 26, 45 and 103 days after sowing. However, at the final phase of growth significant differences were observed with the control registering the highest leaf dry weight.

The two population densities showed marked difference in leaf dry weight from 103 days onwards. The low population density was much more efficient for dry matter accumulation in leaves. Only at 103 days after sowing, the effects of interactions were found to be varying widely. The combination of low population density with 63 per cent and 39 per cent germination levels were significantly superior to other combinations.

Table 7. Effect of germination levels and plant population on dry weight of leaves (g) per plant.

Population / Germination level	Days after sowing											
	26			45			103			122		
	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean
g_1	0.8230	0.7716	0.7973	3.74	3.42	3.58	8.84	7.57	8.20	12.48	9.19	10.84
g_2	0.7214	0.7279	0.7247	3.68	3.28	3.48	10.27	6.89	8.58	11.69	5.85	8.77
g_3	0.8812	0.5586	0.7199	4.03	3.41	3.72	8.41	7.73	8.07	9.77	5.10	7.43
g_4	0.8324	0.7262	0.7793	3.97	3.73	3.85	12.66	6.39	9.53	9.71	4.76	7.24
Mean	0.8145	0.6951		3.85	3.46		10.05	7.15		10.91	6.23	
C.D. (0.05)		-			-		for Marginal means of combination = 2.53; P = 1.27			for marginal means of G = 1.96; p = 1.38		
SE/plot ±		0.1999			0.71			1.45			1.58	

4.2.4. Stem dry weight

The mean values of observation are given in Table 8 and 9 and in Fig. 8. It is seen from the results that the germination levels did not influence the stem dry weight at 10, 20, 26 and 103 days after sowing. At 15 days after sowing, the 63 per cent germination level recorded the highest value followed on par by the 48 per cent level of germination. However, the 63 per cent level of germination possessed distinct superiority over other levels unlike 48 per cent. During the rest of the period of observation also appreciable difference in the effect of germination levels could be seen except at 103 days after sowing. But it was the control that ranked superior to all other germination levels which were on par with others. However, at the final phase the control was on par with the 63 per cent germination level.

The two plant population levels started registering significant effect on stem dry weight from the 45th day onwards. Throughout the period of crop growth, the low population density recorded higher values. At no stage the interaction effects were found to vary markedly.

Table 9. Effect of germination levels on dry weight of stem per plant (mg) (upto 20 days).

Germination level	Days after sowing		
	10	15	20
g_1	40.13	51.12	96.50
g_2	40.37	63.60	95.67
g_3	36.62	57.90	86.30
g_4	39.27	49.95	103.65
C. D. (0.05)	-	9.41	-
SE/plot ±	2.96	7.65	12.97

4.2.5. Height of plants

Tables 10 and 11 depict the effect of germination levels and plant population on plant height. The treatments did not vary significantly except at 122 days after sowing. At this stage, the 72 per cent level (control) was significantly superior to the plants from deteriorated seeds. The population density did not exert any marked influence on plant height. It was also the case with population density-germination level interactions.

4.2.6. Number of branches per plant

The data pertaining to branch number as influenced by seed deterioration and planting densities are given in

Table 9. Effect of germination levels and plant population on dry weight of stem (g) per plant.

Population / Germination level	Days after sowing											
	26			45			103			122		
	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean
g_1	0.2648	0.2587	0.2618	2.71	1.68	2.20	10.15	8.69	9.42	17.10	10.49	13.80
g_2	0.2611	0.3072	0.2841	1.54	1.25	1.39	13.38	9.58	11.48	16.60	8.60	12.60
g_3	0.2884	0.2010	0.2447	1.73	1.38	1.56	11.38	8.22	9.80	13.88	7.43	10.66
g_4	0.2871	0.2361	0.2616	1.77	1.02	1.39	10.12	6.24	8.13	14.29	6.69	10.49
Mean	0.2754	0.2508		1.93	1.33		11.23	8.19		15.47	8.30	
CD(0.05)		-		for marginal means of g = 0.47, p = 0.33			for marginal means of p = 2.83			for marginal means of g = 2.604, p = 1.84		
SE/Plot ±		0.072			0.379			3.23			2.10	

Table 10. Effect of germination levels on plant height (cm) (upto 20th day).

Germination level	Days after sowing	
	15	20
g_1	7.37	10.35
g_2	8.43	10.55
g_3	8.23	9.46
g_4	7.29	11.12
C.D. (0.05)	-	-
SE/plot ±	0.96	1.06

Table 12 and Fig. 9. Plant populations only differed significantly at all stages of observation with respect to the number of branches, the low population density being distinctly superior.

4.2.7. Flowering

The data on the emergence of first flower and attainment of 50 per cent flowering are given in Table 13. Number of days required for flowering initiation varied significantly with the levels of seed deterioration. Early flowering was observed in the deteriorated seed lots. Effect of plant population was not marked in this respect. Also the differences between treatments were not pronounced in the case of 50 per cent flowering.

Table 11. Effect of germination levels and plant population on height of plants (cm).

Population / Germination level	Days after sowing: 26			45			103			122		
	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean
g_1	10.39	10.95	10.67	16.47	14.82	15.64	45.67	43.33	44.50	62.78	54.56	58.67
g_2	11.00	10.37	10.69	16.24	18.34	17.29	37.00	43.00	40.00	45.89	39.67	42.78
g_3	10.76	10.32	10.54	16.37	15.49	15.93	40.33	37.66	39.00	40.78	40.89	40.83
g_4	10.39	9.41	9.90	16.01	18.01	17.01	38.57	38.33	38.50	51.22	40.33	45.78
Mean	10.66	10.26		16.27	16.67		40.42	40.58		50.17	43.86	
C.D. (0.05)		-			-			-		For marginal means of g = 9.43		
S.E./plot ±		0.87			2.61			6.03			7.6	

Table 12. Effect of germination levels and plant population on number of branches per plant.

Population / Germination level	Days after sowing								
	45			103			122		
	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
g_1	2.55	1.56	2.03	4.00	2.00	3.00	6.11	3.33	4.72
g_2	3.00	2.56	2.78	5.67	4.67	5.17	6.44	4.22	5.33
g_3	3.10	2.00	2.55	6.33	4.67	5.50	6.44	3.89	5.17
g_4	3.45	2.00	2.72	5.33	4.0	4.67	6.22	3.44	4.83
Mean	3.03	2.03		5.33	3.83		6.30	3.72	
CD(0.05)	for marginal means of p = 0.803			for marginal means of p = 1.35			for marginal means of p = 0.68		
SE/plot ±		0.92			1.54			0.77	

Table 13. Effect of germination levels and plant population on flowering.

Population germination level	Number of days for first flower emergence			Number of days to 50 % flowering		
	P_1	P_2	Mean	P_1	P_2	Mean
g_1	57.67	55.66	58.33	99.00	101.33	100.17
g_2	50.33	50.33	50.33	98.67	100.67	99.67
g_3	50.00	51.33	50.67	99.00	98.67	98.83
g_4	50.33	51.67	51.00	90.67	98.67	91.67
Mean	52.08	52.25		96.83	99.83	
C.D. (0.05)	for marginal means of g = 3.18				-	
SE/plot ±		2.57			7.68	

Fig.9: Effect of germination levels and plant population on number of branches per plant.

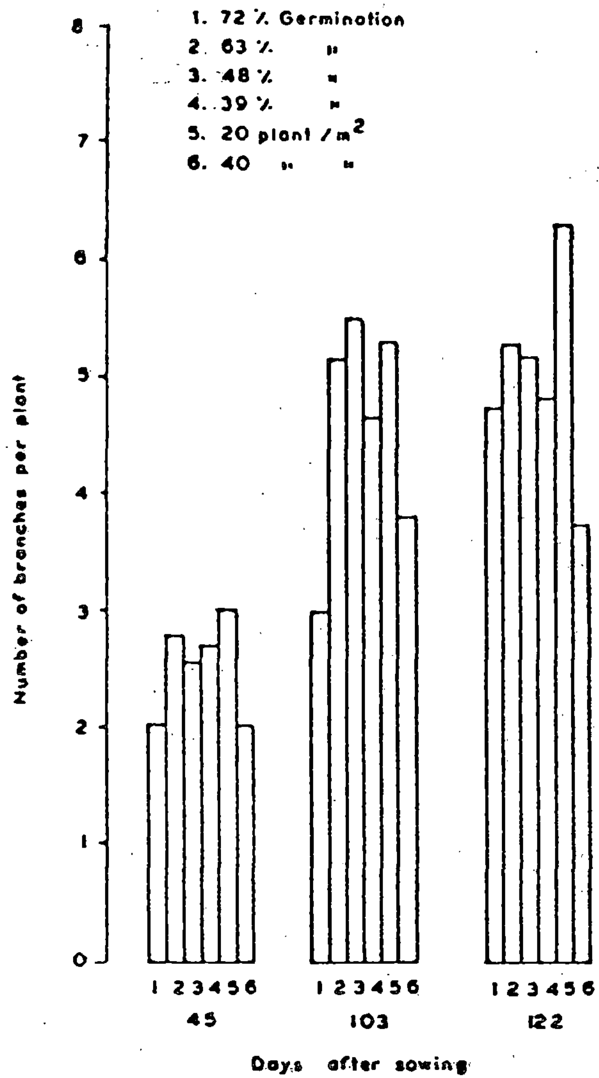
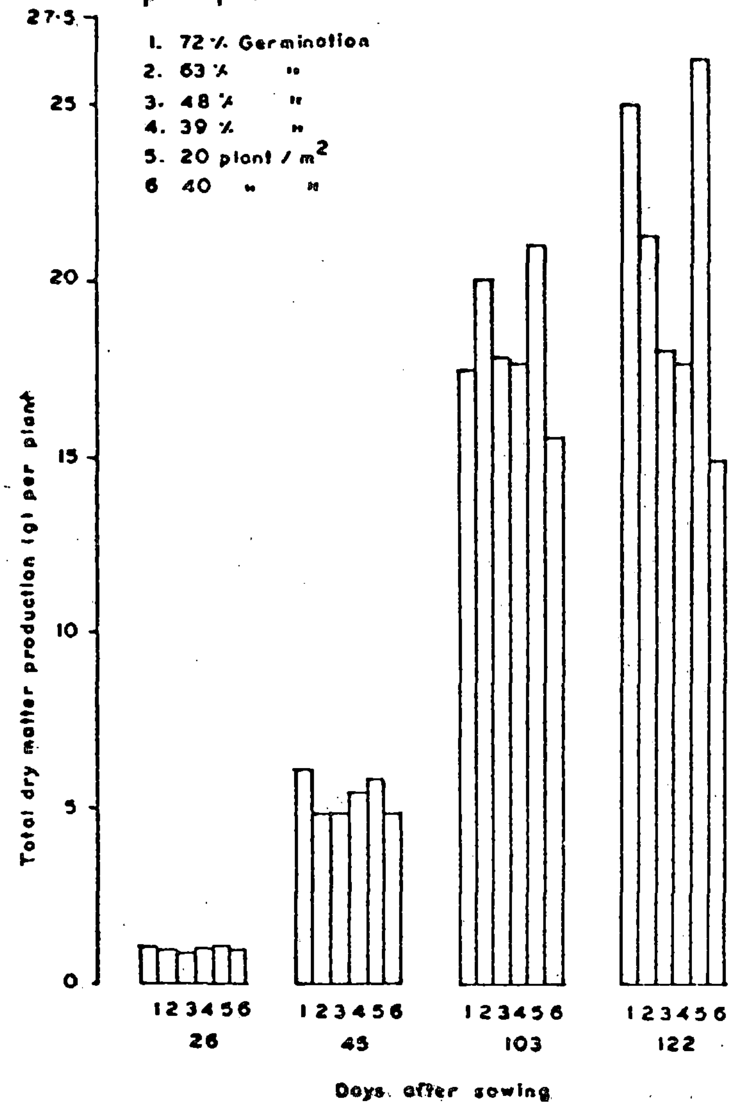


Fig.10. Effect of germination levels and plant population on total dry matter yeild (g) per plant.



4.2.8. Total dry matter yield

The data on total dry matter yield are given in Table 14 and 15 and Fig. 10. At the first phase the plants from maximum deteriorated seeds recorded the highest dry matter accumulation, but it was not statistically significant to control. On the 15th day after sowing, a reverse trend on total dry matter was observed with the degree of seed deterioration except for the control. During the next phase, though the differences were not significant, the control plants accumulated maximum dry matter. Similarly, the differences in dry matter accumulation were not prominent at 26 days after sowing, but showed the same trend as that for 20 days after sowing.

Table 14. Effect of germination levels on total dry matter yield (mg) per plant.

Germination level	Days after sowing		
	10	15	20
G_1	95.20	115.20	344.02
G_2	93.62	149.27	314.10
G_3	92.30	138.09	332.20
G_4	100.74	125.18	314.93
C.D. (0.05)	5.92	11.88	-
SE/plot ±	4.81	9.66	45.33

Table 15. Effect of germination levels and plant population on total dry matter yield (g) per plant.

Population / Germination level	Days after sowing											
	26			45			105			122		
	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean
g_1	1.088	1.030	1.059	6.48	5.77	6.12	18.99	15.93	17.46	29.58	19.68	24.63
g_2	0.982	1.035	1.009	5.22	4.53	4.87	23.65	16.48	20.[illegible]	28.29	14.46	21.38
g_3	1.169	0.759	0.965	5.75	4.04	4.89	19.80	15.96	17.8[illegible]	23.65	12.53	18.09
g_4	1.119	0.962	1.041	5.74	5.0[illegible]	5.41	21.34	13.97	17.65	24.00	11.45	17.73
Mean	1.090	0.945		5.79	4.86		20.95	15.58		26.38	14.53	
C.D. (0.05)		-		for marginal means of g = 0.34, p = 0.66			for marginal means of p = 3.30			for marginal means of p = 2.93, G = 4.14		
SD/plot ±		0.264			0.758			3.77			3.34	

At 45 days after sowing the plants from the undeteriorated seeds recorded maximum dry matter yield which was on par with the maximum deteriorated seeds. The seed deterioration had no major impact on the total dry matter yield per plant at 105 days also. Towards the final phase of crop growth, the control plants recorded the highest dry matter yield per plant, which was on par with the 65 per cent germination level. Since no difference in yield between 12 and 24 plants/m^2 have been reported (Chaturvedi et al., 1980), we chose to study the effects of higher plant population on dry matter yield. The total dry matter yield at 20 plants/m^2 was significantly superior to 40 plants/m^2 from 45th day onwards. The pod yield per plant at harvest also was significantly more in the low population density.

The interaction effects were not pronounced at any of the stages.

4.2.9. Relative growth rate (RGR)

Observations on RGR are presented in Table 16. The RGR values were markedly influenced by the germination levels. The plants from maximum deteriorated seeds recorded the lowest RGR values during the period between 10 and 20 days after sowing, which was significantly inferior to the other levels of seed deterioration and control which were

Table 16. Effect of germination levels and plant population on relative growth rate (RGR) (mg/g/day).

Population / Germination level	Days after sowing								
	Between 10 and 20			Between 20 and 45			Between 45 and 103		
	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean
g_1	0.0539	0.0545	0.0542	0.0513	0.0498	0.0506	0.0080	0.0077	0.0078
g_2	0.0524	0.0524	0.0524	0.0480	0.0467	0.0474	0.0114	0.0097	0.0106
g_3	0.0553	0.0541	0.0547	0.0492	0.0443	0.0468	0.0092	0.0100	0.0096
g_4	0.0488	0.0481	0.0484	0.0504	0.0490	0.0497	0.0097	0.0075	0.0086
Mean	0.0526	0.0523		0.0497	0.0475		0.0096	0.0087	
CD(0.05)	for marginal means of g = 0.0047			for marginal means of g = 0.0029, p = 0.0021			for marginal means of g = 0.0017; for combination = 0.0025		
SE/plot ±		0.0033			0.0023			0.0014	

on par. During the period between 20 and 45 days after sowing control was significantly superior to the deteriorated seeds except the least viable. A distinctly superior effect of low population density on RGR was evident at this stage.

During the period between 45 and 103 days after sowing, the 63 per cent germination level possessed the highest RGR which was significantly superior to the undeteriorated control and the maximum deteriorated lots. The marginal means for population densities were not significantly different. However, the interactions between population density and levels of germination were significant. The low population density-63 per cent germination combination had the fastest RGR at this stage. However, this was on par with not only with the high population density-48 per cent germination and 63 per cent germination but also with the low density-39 per cent germination combination.

4.2.10. Yield components

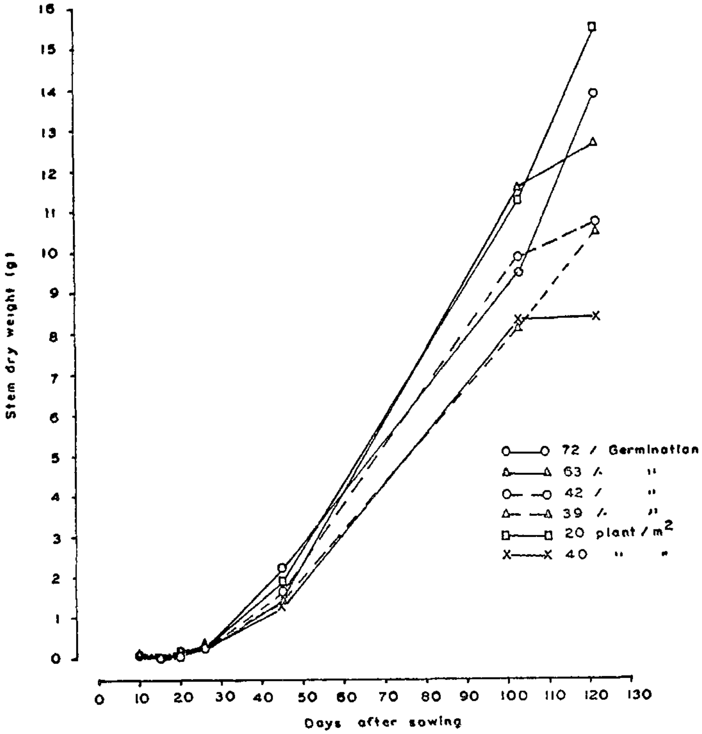
Effect of germination levels and planting density on various yield components are presented in Table 17. The results revealed that seed deterioration and plant population exerted no prominent effect on the various yield components such as pod number, grains per pod, length of

Table 17. Effect of germination levels and plant population on yield components.

Population / Germination level	Number of pods per plant			Number of grains per pod			Length of pods (cm)		
	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
g_1	4.80	3.13	3.97	9.60	9.20	9.40	13.67	13.34	13.50
g_2	4.27	5.60	4.93	9.57	9.03	9.30	14.61	13.94	14.28
g_3	5.20	4.00	4.60	8.13	7.10	7.62	13.86	12.38	13.12
g_4	8.53	5.40	6.97	7.10	8.93	8.02	12.86	13.17	13.02
Mean	5.70	4.53		8.60	8.57		13.75	13.21	
CD(0.05)		-			-			-	
SE/plot ±		1.99			1.49			0.79	

Dry weight of pods/plant (g)			Dry weight of pod cover/10 pods (9)			Dry weight of grains per 10 pods (9)		
P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
4.13	3.01	3.57	4.63	3.29	3.96	6.78	6.17	6.48
3.69	3.14	3.41	3.93	3.46	3.69	7.68	6.85	7.27
3.63	2.95	3.29	3.53	2.86	3.19	7.02	6.72	6.90
2.79	3.18	2.98	3.91	3.09	3.50	5.10	6.57	7.33
3.56	3.07		4.00	3.18		6.90	7.07	
for marginal means of p = 0.42			for marginal means of p = 0.42				-	
	0.47			0.48			1.30	

Fig 8 Effect of germination levels and plant population on dry weight of stem per plant (g)



pods and dry weight of grains per 10 pods. However, the dry weight of pods per plant and the dry weight of pod covers from 10 pods were remarkably influenced by the population density. In both cases the low density was significantly superior to the high density.

4.2.11. Nitrogen content of leaves

The data on leaf nitrogen content are presented in Table 18. Leaf nitrogen content was more at 45 days after sowing, then decreased till 103 days and again increased by the 122nd day. The differences between combinations were significant only at 45 days after sowing. Leaf nitrogen was maximum in the low population density-63 per cent germination combination. The variations were not prominent in the other combinations. At 122 days after sowing, the low population density possessed significantly higher percentage of nitrogen in the leaf.

4.2.12. Nitrogen content of stem

Table 19 presents the data on stem nitrogen content. The differences were marked only at the final stage. The control and the 63 per cent germination level were on par and were superior to other levels of germination. Also the low density planting was markedly inferior to the high population density.

Table 18. Effect of germination levels and plant population on leaf nitrogen content (%).

Population / Germination level	45			103			122		
	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean
g_1	3.01 (112.57)	3.81 (130.03)	3.40 (121.30)	2.95 (260.78)	3.17 (239.97)	3.06 (250.38)	3.23 (403.10)	3.25 (298.68)	3.24 (350.89)
g_2	4.24 (156.03)	3.20 (104.98)	3.72 (130.51)	2.57 (263.94)	2.85 (196.37)	2.71 (230.16)	4.12 (481.63)	3.26 (190.71)	3.69 (336.17)
g_3	3.86 (155.55)	3.65 (124.47)	3.75 (140.01)	3.04 (255.65)	3.15 (243.50)	3.09 (249.58)	3.65 (356.61)	3.35 (170.85)	3.50 (263.73)
g_4	3.26 (129.42)	4.49 (167.48)	3.87 (148.45)	2.99 (378.53)	2.83 (180.84)	2.92 (279.69)	4.05 (393.26)	3.36 (159.94)	3.70 (276.6)
Mean	3.59 (138.39)	3.79 (131.74)		2.89 (289.72)	2.99 (215.17)		3.76 (408.69)	3.51 (205.05)	
CD(0.05)	for combination = 0.653				-		for marginal means of p = 0.425		
SE/plot ±		0.373			0.548			0.485	

Figures in parentheses indicate leaf nitrogen content (mg) per plant (% was not calculated).

Table 19. Effect of germination levels and plant population on stem nitrogen content (%).

Population / Germination level	Days after sowing								
	45			103			122		
	p_1	p_2	Mean	p_1	p_2	Mean	p_1	p_2	Mean
g_1	1.54 (41.73)	1.51 (25.37)	1.53 (33.59)	0.97 (98.46)	1.14 (99.07)	1.06 (98.77)	1.15 (196.65)	1.17 (122.73)	1.16 (159.69)
g_2	1.79 (27.57)	1.49 (18.63)	1.64 (23.10)	1.05 (140.45)	1.04 (99.63)	1.05 (120.04)	1.08 (179.28)	1.25 (107.50)	1.16 (143.39)
g_3	1.51 (26.13)	1.74 (24.01)	1.62 (25.07)	1.03 (117.21)	1.08 (88.78)	1.06 (102.99)	1.01 (140.19)	1.08 (80.24)	1.05 (110.22)
g_4	1.43 (25.31)	1.51 (15.40)	1.47 (20.36)	0.99 (100.19)	1.01 (63.02)	1.00 (81.16)	0.87 (124.32)	1.04 (69.58)	0.96 (96.95)
Mean	1.57 (30.19)	1.56 (20.05)		1.01 (114.08)	1.07 (87.63)		1.03 (160.11)	1.14 (95.61)	
CD (0.05)		-			-		For marginal means of g = 0.124 p = 0.087		
SE/plot ±		0.2250			0.84			0.87	

Figures in parentheses indicate stem nitrogen content (mg) per plant (CD was not calculated).

4.2.13. Nitrogen content of grains

The observations in this respect are detailed in Table 20. Neither the germination levels nor the population density were found to influence the grain nitrogen content to a significant level.

4.2.14. Total uptake of nitrogen per plant

The data are portrayed in Table 20. There was a reduction in total nitrogen uptake per plant with increasing seed deterioration and population density. The control and 63 per cent germination level were significantly superior to other levels of seed deterioration.

4.2.15. Total uptake of nitrogen per hectare

Regarding germination levels the trend was the same as that of nitrogen uptake per plant. However, the response of population density was totally different, the high density being distinctly superior to the low one (Table 20).

Table 20. Effect of germination levels and plant population on grain nitrogen content (%), total nitrogen uptake (mg) per plant and total nitrogen uptake (kg) per hectare.

Population / Germination level	Grain nitrogen content (%)			Total nitrogen uptake (mg) per plant			Total nitrogen uptake (kg) per hectare		
	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
g_1	3.22 (132.99)	3.62 (108.96)	3.42 (120.98)	732.74	530.47	631.61	14.64	21.42	18.03
g_2	3.57 (131.73)	3.62 (113.67)	3.60 (122.7)	792.64	411.46	602.05	15.61	16.71	16.16
g_3	3.31 (120.15)	3.76 (110.92)	3.54 (115.54)	616.85	362.04	489.45	12.42	14.44	13.43
g_4	3.43 (95.69)	4.06 (129.11)	3.75 (112.4)	612.21	357.4	484.81	12.17	14.29	13.23
Mean	3.38 (120.14)	3.77 (115.67)		688.61	415.34		13.71	16.72	
CD (0.05)		-		for marginal means of G = 103.6, P = 72.7			for marginal means of G = 2.94, P = 2.08		
SEm/plot ±		0.466			83.1			4.38	

Figures in parentheses indicate grain nitrogen content (mg) per plant (CD not calculated).

5. DISCUSSION

Field and laboratory investigations were conducted to evaluate the effect of seed deterioration on growth and dry matter production in an indeterminate cultivar of cowpea. Four levels of germination viz. 72, 63, 48 and 39 per cent were obtained by utilizing the accelerated ageing technique. These were sown in the field at two plant populations viz. 20 and 40 plants/m^2. The results have been described in the preceding chapter and are discussed below.

5.1. Field Emergence

The deteriorated seed lots germinated faster than the undeteriorated control. The low initial germination in the control could be due to the time taken for hydration of the seed (initial seed moisture content 7.45 per cent), whereas in other cases the seeds were conditioned to 26.68 per cent moisture to create variability in germination level. Thus the initiation of root and shoot started earlier in the conditioned seed lots. The rate as well as total field emergence were inversely related to the degree of deterioration. Corroboratory results were obtained by Woodstock et al. (1970) and Agrawal and Singh (1975) in the case of soybeans and Harrison (1977) for barley.

among the aged seeds. At later stages, the control along with slightly deteriorated lots (63 per cent germination) assumed superiority over other deterioration levels.

Three types of chromosomal damages were reported from low viability seed lots - gross chromosomal aberrations (Abdalla and Roberts, 1968) which may be deleted during cell division; small chlorophyll mutations which segregate in later generations (that persist through to seed production) and chromosomal damage of intermediate intensity which may be selected out during meristematic cell division, but takes longer to disappear than the more obvious aberrations (Abdalla and Roberts, 1969a). It is possible that these variations at the final phase could be due to the persistent nuclear damages.

At the final phase, the control and 63 per cent germination level were at par and the two more deteriorated lots at par in the case of leaf area and stem dry weight. From this it could be derived that a drop in germination to about 60 per cent would not affect the factors significantly. But if there is considerable drop in germination, the leaf area of the plant, which is the working capital of the plant, and stem dry weight would be affected. However, leaf dry weight followed a slightly different pattern. That is at the final phase of crop growth the control is significantly superior to the

63 per cent germination level. The difference could be due to the variations in leaf thickness which may be due to an impeded translocation of photosynthates.

In the case of 39 per cent germination level, there existed an inverse relationship between stem dry weight and leaf dry weight on the 103rd day after sowing. At this stage 39 per cent germination level registered the highest leaf dry weight and the lowest stem dry weight among the various germination levels. This could be explained on the basis of an accumulation of photosynthates in the leaves.

The difference between population densities could be explained on the basis of competition for inputs which was more on the high density planting.

5.3. Flowering

Flower initiation took more time in the control, compared to the deteriorated levels. This could be due to the more active vegetative growth phase as evident from the dry weight of leaves and stems. However, for 50 per cent flowering the germination levels and population densities did not vary much.

5.4. Total dry matter yield

At 10 and 15 days after sowing, the 39 and 63 per cent germination levels recorded the highest dry matter yield, respectively. This could be explained on the basis of the high leaf area obtained at these stages and the consequent high photosynthetic surface available. The pattern of dry matter accumulation follows essentially the same pattern of leaf area expansion. That is, at the final stage, the more deteriorated seeds had significantly low dry matter production. Chirkovskii (1953) also reported a reduced yield of leaves per plant in the case of aged tobacco seeds. Similarly Perry and Harrison (1977) observed lower grain yields from deteriorated seed lots in the case of barley.

It could be seen that the use of deteriorated seeds would be unlikely to have a significant effect on yield, provided the viability is around 60 per cent. However, appropriate compensatory seed rates must be used in order to have an optimum plant population. According to Abdalla and Roberts (1969b), in the species of barley, broad beans and peas, if the viability is above 50 per cent and provided the low viability is adjusted by increasing seed rates, the crop yields won't be affected.

Since the variety is of indeterminate growth habit, the transformation from vegetative to reproductive phase was not perfect due to climatic factors. Therefore, it was not possible to probe the influence of loss of viability on grain yield. There could also be varietal differences in respect of loss of viability-yield relationships. Harrison (1966) working on lettuce reported that in some varieties some loss of yield potential may occur before there is a significant loss of viability. It has to be further ascertained whether this type of an influence prevails in this species also.

5.5. Relative growth rate (RGR)

Between 10 and 20 days after sowing, the treatments 48 and 72 per cent germination levels had the highest values of RGR (Table 16). However, control, 63 and 40 per cent germination levels were on par at this stage. From this it can be seen that at higher deterioration levels the growth rates were significantly low in the begining. This is in conformity with the findings of Abdalla and Roberts (1969b) and Harrison (1977). However, at later stages RGR values did not follow a consistent pattern. The RGR was maximum between 10 and 20 days in all treatments and later it declined gradually. At no stage until 103 days after sowing, the RGR was found to be negative. This would indicate that all the photosynthetic organs like leaf, stem etc. remained functional which was expected from an indeterminant variety. Nevertheless, the rate of photosynthesis/rate of respiration must have declined/ increased with age.

5.6. Uptake of nitrogen

In general, the nitrogen content in leaves and stem was greater at 45 days after sowing which declined at 103 days. The decrease in nitrogen content indicated the redistribution of nitrogen from leaf and stem to pods which had started to develop by that time. The mobilised nitrogen from leaf did not accumulate in stem as indicated by the low stem nitrogen content. At 122 days after sowing, the leaf nitrogen percentage increased again by assimilation which again did not accumulate in the stem. Despite the mobilization of nitrogen from leaf and stem to developing pods, a considerable amount of nitrogen was still left in these organs which was more than what was left in cereals. Similar results have been reported by Chaturvedi et al. (1980).

Regarding total uptake per plant at the final stage (Table 18) the differences were significant. The total nitrogen uptake per plant followed the same pattern as that of dry matter accumulation. The differences between treatments were mainly due to the variations in dry matter production rather than any difference in percentage tissue nitrogen content. Due to higher competition among the individuals, the high density planting had significantly lower amount of nitrogen per plant.

However, with respect to the total nitrogen uptake per hectare the pattern was different in the case of population density. This obviously was due to the more number of plants that were present in the high density planting per unit area. Consequent to this the total nitrogen uptake per hectare was significantly more the denser planting. Regarding seed deterioration, the pattern of nitrogen uptake followed the same trend as that of total dry matter accumulation and accumulation of nitrogen in the plant tissue on a per plant basis.

6. SUMMARY AND CONCLUSIONS

An investigation was conducted at the Division of Seed Technology, Indian Agricultural Research Institute, New Delhi to study the effect of loss of viability on growth and yield of cowpea and to find out whether the deleterious effects due to loss of viability could be compensated by increasing the plant population per unit area. The treatments comprised of four levels of germinations (72, 63, 48 and 39 per cent) and two plant populations (20 and 40 plants/m^2). The field experiment was laid out in a 4 x 2 factorial randomised block design with three replications. The crop was sown on 22nd of March, 1980 and harvested on 19th of July, 1980. The findings are summarised below :

1. In order to create variability in germination percentage accelerated ageing treatment was given. During accelerated ageing, seed deterioration was maximum between 2nd and 3rd week after treatment. There was no deterioration during the first week. The length of root, shoot and their dry weights did not vary much until 3rd week after treatment. However, there was a drastic reduction in these attributes during the 4th week.

2. The rate as well as total field emergence were inversely related to the seed deterioration.

3. Leaf area decreased with seed deterioration at the final phase of crop growth. Similarly the low population density was superior to the high one.

4. Regarding leaf dry weight, the control and the low population density were significantly superior to other treatments at the time of harvest.

5. Germination levels 72 and 63 per cent had significantly more stem dry weight per plant. Similarly the low population density registered higher dry matter accumulation in the stem.

6. The germination levels exerted no significant influence on plant height except at the final stage when control recorded the highest value. The effect of planting densities on height was also not markedly evident at any of the stages.

7. The low population density had invariably higher number of branches per plant at various stages of observation. Regarding the effect of germination levels, they were not statistically different.

8. Appearance of first flower was significantly earlier in the plants from deteriorated seed lots. The population density had no marked bearing on this aspect.

9. Total dry matter yield was highest in the plants from the maximum deteriorated seed lot during the early stage. However, at later stages the control plants accumulated maximum dry matter which was on par with the 63 per cent germination level.

10. Relative growth rate was least in the maximum deteriorated seeds in the beginning. But control registered the least value during the period between 45 and 103 days after sowing. The 63 per cent and 48 per cent germination levels were having significantly higher values at this stage.

11. The various yield components were not significantly influenced by the germination levels. However, population density had a marked bearing on the pod dry weight per plant and the dry weight of pod covers.

12. The low population density tended to increase the leaf nitrogen content at the final stage. However, the interaction effects were significant on the 45th day after sowing, with maximum leaf nitrogen content in the low population-63 per cent germination combination.

13. With regard to stem nitrogen content, the control and 63 per cent germination level were significantly superior to other deteriorated lots at the final phase of crop growth. Similarly the plants of high density planting had remarkably more stem nitrogen than the low density.

14. Neither the germination level nor the population density did significantly influence grain nitrogen content.

15. Nitrogen uptake followed the same trend as that of total dry matter yield except in the case of total nitrogen uptake per hectare with reference to the population density.

From this study, therefore, we may conclude that the four germination levels can be grouped into two distinct categories considering the loss of viability-yield relationships in cowpea. The control and the 63 per cent constituted the first group, where no deleterious effects of seed deterioration was noted. The 46 and 39 per cent germination levels forms the second group where a significant reduction in terms of the various growth attributes and dry matter yield was observed. This would, then, mean that the use of old seeds would not have a significant effect on yield, provided that viability is around 60 per cent and appropriate compensatory seed rates are used to allow for that fraction of seed population which is non-viable.

7. LITERATURE CITED

Abdalla, F.H. and Roberts, E.H. 1968. The effects of temperature, moisture and oxygen on the induction of chromosome damage in seeds of barley, broad beans and peas during storage. Ann. Bot. 32 : 119-36.

Abdalla, F.H. and Roberts, E.H. 1969a. The effects of temperature and moisture on the induction of genetic changes of seeds of barley, broad beans and peas during storage. Ibid. 33 : 153-67.

Abdalla, F.H. and Roberts, E.H. 1969b. The effect of seed storage conditions on the growth and yield of barley, broad beans and peas. Ibid. 33 : 169-84.

Agrawal, P.K. and Sinha, J.N. 1975. Laboratory germination and field emergence in soybean Glycine max L. Merr. Seed Res. 3(2) : 111-12.

Barton, L.V. 1961. Seed Preservation and Longevity. Leonard Hill Ltd., London.

Barton, L.V. and Garman, H.R. 1946. Effect of age and storage conditions of seeds on the yields of certain plants. Contr. Boyce Thomson Inst. Pl. Res. 14 : 243-55.

Brown, C.M. 1962. Effect of age of seed on performance of several oat varieties. Agron. J. 54 : 519-20.

Chalam, G.V., Singh, Amir and Douglas, J.E. 1967. Seed Testing Manual. Indian Council of Agricultural Research and United States Agency for International Development, New Delhi.

Chathurvedi, G.S., Agrawal, P.K. and Sinha, S.K. 1980. Growth and yield of determinate and indeterminate cowpeas in dryland agriculture. J. Agric. Sci. Camb. 75 : 89-99.

Chang, C.W. and Calhoun, W. Jr. 1968. Productivity of 10 year old canned forage seeds. Agron. J. 60 : 393-4.

*Chirkovskii, V.I. 1953. The influence of seeds on the development of tobacco plants. Doklady Akad. Nauk S.S.R. 1953, 92 : 439-42.

*Crocioni, A. 1934. Influenza dell' eta del seme sulla sviluppo della planta. Nuori Annoli Agric. Abstract in Proc. Int. Seed Test. Ass. 8 : 93.

Delouche, J.C. and Baskin, C.L. 1973. Accelerated ageing techniques for predicting the relative storability of seed lots. Seed Sci. and Technol. 1(2) : 427-52

Donald, C.M. 1963. Competition among crop and pasture plants. Adv. Agron. 15 : 17-23.

Dungan, G.H. and Koehler, B. 1944. Age of seed corn in relation to seed infection and yielding capacity. J. Am. Soc. Agron. 36 : 436-43.

Harrison, B.J. 1966. Seed deterioration in relation to storage conditions and its influence upon germination, chromosomal damage and plant reference. J. natn. Inst. Agric. Bot. 10 : 644-63.

Harrison, J.G. 1977. The effect of seed deterioration on the growth of barley. Ann. appl. Biol. 87 : 485-94.

Helmer, J.D., Delouche, J.C. and Leinhard, M. 1962. Some indices of vigour and deterioration of seeds of crimson clover. Proc. Assoc. Off. Seed Anal. 52 : 154-61.

/ Novozamsky, I., van Eck, R., van Schouwenburg, J. Ch. and Walinga, I. 1974. Total nitrogen determination in plant material by means of the indophenol-blue method. Neth. J. agric. Sci. 22 : 3-5.

Panse, V.G. and Sukhatme, P.V. 1967. Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi.

Perry, D.A. and Harrison, J.G. 1977. Effects of seed deterioration and seed-bed environment on emergence and yield of spring-sown barley. Ann. appl. Biol. 86 : 291-300.

Roberts, E.H. 1972. Loss of viability and crop yields. In Roberts (E.H.) : Viability of Seeds. Chapman and Hall London. p. 307-320.

Rodrigo, P.A. 1939. Study on the vitality of old and new seeds of mungo. Phillipp. J. Agric. 10 : 265-91.

*Rushing, T. T. 1969. Evaluation of methods for predicting storage potential of tall fescue, crimson clover, sorghum and wheat seed lots in storage. M.S. Thesis. State Univ. Mississippi.

Sinha, S.K. 1974. Yield of grain legumes. Problems and prospects. Ind. J. Gen. and Pl. Breeding. 34 : 988-94.

Sinha, S.K. and Khanna, R. 1975. Physiological, Biochemical and Genetic basis of heterosis. Adv. Agron. 27 : 123-74.

Snedecor, G. W. and Cochran, W.G. 1967. Statistical Methods. 6th ed. Oxford and IBH Publishing Co., New Delhi.

Solomon, M.E. 1951. Control of humidity with potassium hydroxide, sulphuric acid or other solutions. Bull. Ento. Res. 42(3) : 543-54.

Tekrony, D.M. and Egli, D.B. 1977. Relationship between laboratory indices of soybean seed vigour and field emergence. Crop Sci. 17 : 573-77.

Willey, R.W. and Heath. 1969. Quantitative relationships between plant population and crop yield. Adv. Agron. 21 : 281-320.

Woodstock, L.W. 1976. Progress report on the seed vigour testing handbook. Assoc. Off. Seed Anal. Newsletter 52(2) : 1-78.

Woodstock, L.W., Schillinger, J. and Day, A.D. 1970. Laboratory tests and field emergence of soybean seeds. Assoc. Off. Seed Anal. Newsletter 44(2) : 30.

* Original not seen.

Appendix I. Meteorological data for the period from March to July'80 (Weekly means).

Week	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	No. of rainy days
	Max.	Min.	I	II		
16.3.80 to 24.3.80	32	15.46	78.6	34.4	0.36	1
25.3.80 to 31.3.80	30.4	15.17	82.29	34.71	0.54	2
1.4.80 to 7.4.80	33.29	15.33	79.71	34.29	0	0
8.4.80 to 14.4.80	37.96	19.41	72.14	21.00	0	0
15.4.80 to 21.4.80	40.11	21.66	45.14	18.14	0	0
22.4.80 to 28.4.80	41.87	23.21	35.14	10.86	0	0
29.4.80 to 5.5.80	42.81	25.67	25.43	15.57	0	0
6.5.80 to 12.5.80	40.56	24.26	45.0	18.57	0	0
13.5.80 to 19.5.80	43.01	25.33	26.71	13.0	0	0
20.5.80 to 26.5.80	41.93	25.29	29.43	13.71	0	0
27.5.80 to 2.6.80	40.99	25.86	50.71	31.86	1.37	2
3.6.80 to 9.6.80	40.01	25.16	55.71	30.0	0	0
10.6.80 to 16.6.80	39.67	27.91	69.57	40.86	0.69	1
17.6.80 to 23.6.80	38.87	27.9	71.71	53.14	3.34	1
24.6.80 to 30.6.80	36.21	27.5	81.86	64.57	3.14	1
1.7.80 to 7.7.80	35.11	26.16	87.71	70.43	26.94	4
8.7.80 to 14.7.80	31.9	25.47	95.43	83.0	14.63	6
15.7.80 to 21.7.80	32.82	25.73	83.33	76.67	5.47	4