Evaluation of Plant Growth Regulators and Seed Primers for Drought Tolerance in Pigeonpea (*Cajanus cajan* (L.) Millsp.)

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By

Manish Patidar

Department of Genetics and Plant Breeding
Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
R.A.K. College of Agriculture
Sehore (M.P.)

2014

CERTIFICATE – I

This is to certify that the thesis entitled **"Evaluation of plant growth regulators and seed primers for drought tolerance in pigeonpea (*Cajanus cajan* (L.) Millsp.)''** submitted in partial fulfilment of the requirement for the **DEGREE OF MASTER OF SCIENCE (Genetics and Plant Breeding)** of the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bonafied research work carried out by **Mr.Manish Patidar ID.No.RA/SH/313/ 2008** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any degree or diploma (Certificate awarded etc.) or has been published. All the assistance and help received during the course of the investigation has been acknowledged by the scholar.

Place: Sehore　　　　　　　　　　Signature

Date:　　　　　　　　　　**(Dr.A.N.Tikle)**

Chairman of the Advisory Committee

MEMBER OF THE STUDENT'S ADVISORY COMMITTEE

Chairman (Dr. A.N.Tikle)　　　　.......................................

Member (Dr.S.R.Ramgiry)　　　　………………………………

Member (Shri D.K.Raidas)　　　　……………………………….

CERTIFICATE –II

This is to certify the thesis entitled **"Evaluation of plant growth regulators and seed primers for drought tolerance in pigeonpea (*Cajanus cajan* (L.) Millsp.)''** submitted by **Mr.Manish Patidar ID.No.RA/SH/313/ 2008** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfillment of the requirements for the degree of Master of Science in **Agriculture (Genetics and Plant Breeding)** has been accepted after evaluation by the External Examiner and approved by the Student's Advisory Committee after an oral examination on the same.

Signature

Place: Sehore (**Dr.A.N.Tikle**)

Date:

Chairman of the Advisory Committee

MEMBER OF THE ADVISORY COMMITTEE

Chairman (Dr. A.N.Tikle) ....

Member (Dr. S.R.Ramgiry) ……………………………….

Member (Shri D.K.Raidas) ……………………………….

Head of the Department ....

Dean of college ....

Director Instruction ....

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List of Contents

Number	Title	Page
I	Introduction	1-3
II	Review of Literature	4-21
III	Material and Methods/Research Methodology	22-29
IV	Results	29-40
V	Discussion	41-51
VI	Summary, Conclusions and Suggestions for further work	52-57
	References	58-70
	Vita	

List of Tables

Table Number	Title	Pages No
3.1	Monthly meteorological data during crop growth period 2013-14	23
3.2	The skeleton for analysis of variance for randomized complete block design	28
4.1	Mean sum of squares for morpho–physiological and yield traits.	32
4.2	Mean performance for various traits as influenced by different seed hardening chemicals and plant growth regulators.	32
4.3	Mean performance for various traits as influenced by different seed hardening chemicals and plant growth regulators	33
4.4	Mean performance for various traits as influenced by different seed hardening chemicals and plant growth regulators.	34
4.5	Mean performance for various traits as influenced by different seed hardening chemicals and plant growth regulators.	38

List of Figure

Table Number	Title	Pages No
4.1	Plant height at various stages of plant growth in response to seed priming and plant growth regulators.	31
4.2	Day to flower and pod initiation in as influenced by seed priming and plant growth regulators.	31
4.3	Graph showing effect of different seed hardening chemicals and plant growth regulators on drought susceptibility index (%) and relative water loss (mg/min) in pigeonpea.	36
4.4	Graph showing effect of different seed hardening chemicals and Plant growth regulators on flower shedding at 10 and 20 days after flowering in pigeonpea.	36
4.5	Graph showing effect of different seed hardening chemicals and Plant growth regulators on drought tolerance efficiency (%) and relative leaf water content (%).	40
4.6	Graph showing effect of different seed hardening chemicals and Plant growth regulators on seed yield per plant and harvest index (%).	40

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	**Legend**	**Symbol**	**Legend**
		@	At the rate of
^{o}C	Degree Celsius	%	Percent
>	Greater than	<	Less than
/	Per	$\underline{+}$	Plus or Minus
i.e.	That is	√	Square root
NAA	Napthalic acetic acid	CCC	Cycoceal
CD	Critical Difference	cm	Centimeter
CV	Coefficient of Variation	DF	Degree of Freedom
&	And	etc	Etcetera
et al.	Et alia (and others)	Fig.	Figure (s)
g	Gram	RLWC	Relatively Water Content
RWL	Rate of water Lose	DSI	Drought Susceptibility Index
ha	Hectare	K	Potassium
kg	Kilogram (s)	m	Meter (s)
m ha	Million hectare	m t	Million tonnes
M.S.S.	Mean sum of square	DAF	Days after flowering
No.	Number (s)	DAS	Days after sowing
HI	Harvest Index	DTE	Drought Tolerance Efficiency
S.E m.±	Standard error of mean	T	Tones
Viz.	Videlicet (namely)	RCBD	Randomized Complete Block Design

CHAPTER I

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L). Millsp.) is an important grain legume crop of rainfed agriculture in the tropical and sub-tropical areas. Pigeonpea belongs to genus *Cajanus* of sub tribe *Cajaninae* Phaseoleae of the sub-family Papilionoideae under family Leguminosae. The genus *Cajanus comprises* 32 species, most of which are found in India, Australia and one species is native to West Africa (Van der Maesen, 1986). Pigeonpea is cultivated, either as the sole crop or inter crop with soybean, finger millet, sorghum, pearl millet, maize or with short duration legumes.

Pigeonpea is the major source of protein; enriches soil; provides fodder and fuel wood and good for arresting soil erosion. Pigeonpea is grown in 82 countries worldwide either as a field crop or as backyard crop. As a regular crop, it is grown only in 19 countries on 6.22 million ha producing 4.74 million tons of grain. India has the largest area under pigeonpea (4.65 m ha), followed by Myanmar (0.65 m ha), Tanzania (0.29 m ha), Malawi (0.21 m ha), Kenya (0.13 m ha), Uganda (0.11 m ha) and Nepal (0.03 m ha) (FAOSTAT, 2013).

In India, it is cultivated in 4.65 million ha with production of 3.02 million tones and productivity of 650 kg ha^{-1} (FAOSTAT, 2013). In Madhya Pradesh, pigeonpea is cultivated on 0.53 million ha (13.24 %) with annual production of 0.33 million tones (12.60 %) and productivity of 625 kg ha^{-1}in 2011-12 (IIPR, Kanpur, 2013).

Pulses are mainly grown undar agro-ecological constraints Cultivation of pulses is in rainfed situation, is more than 95 per cent area is under these crops are still rainfed. In deficient soils, the application of micronutrients has been found to be beneficial but hardly any one uses them. The growth promoter’s viz., NAA, miraculan, cytozyme and triacontanol enhance the fruit set by preventing the flower drop in number of crops. The mechanism involved is through the hormone directed translocation of photoassimilates, counteracting the effects of endogenous growth retardants like ABA and ethylene and also improving the partitioning efficiency. Hence, it is necessary to integrate the efforts to boost up productivity of pulses in general and pigeonpea in particular

As early as in 1964, Henckel developed these wetting and drying treatments of seeds for imparting resistance to drought and adverse conditions. Seed hardening with chemicals is of greater significance in overcoming drought situations. In recent years, this technology is gaining more importance owing to its simplicity and cost effectiveness. Since pigeonpea is a long duration crop and is grown under rainfed situations, there is a need for seed hardening to overcome terminal water stress. To get assured returns, one has to go for cultivating drought tolerant varieties for which breeding for drought resistance is essential, which is time consuming, tedious and requires adaptability of the genotypes over a wide range of agro-ecological situations. One of the major problems in pigeonpea is flower drop, particularly, at later stages due to terminal stress (Ramarao, 2004). It has been envisaged that better technology, particularly the use of plant growth regulators are known to improve the physiological efficiency of plants through increased photosynthetic ability and also known to enhance the source-sink relationship and stimulate the better translocation of photoassimilates towards the developing pods. In deficient soils, the application of micronutrients has been found to be beneficial but hardly any one uses them. The growth promoters *viz*., NAA and Triacontanol enhance the fruit set by preventing the flower drop in number of crops. The mechanism involved is through the hormone directed translocation of photoassimilates, counteracting the effects of endogenous growth retardants like ABA and ethylene and also improving the partitioning efficiency. Hence, it is necessary to integrate the efforts to boost up productivity of pulses in general and pigeonpea in particular. Hence, we can think of alternative methods to induce drought tolerance in pigeonpea through which the productivity potential can be enhanced. With this background, the present investigation was carried out with the following objectives;

1. To study the effect of seed primers *viz.* KCl and $CaCl_2$ at different concentrations on drought tolerance induction and enhancing productivity in pigeonpea.
2. To study the role of plant growth regulators *viz.,* NAA and Triacontanol at different stages of crop growth in increasing the retention of flowers and fruit set .
3. To study the influence of plant growth regulators on yield enhancement in pigeonpea genotype.

CHAPTER II
REVIEW OF LITERATURES

Pulses, besides being an indispensable component of vegetarian diet, play a vital role in sustaining long term productivity of soil through biological nitrogen fixation. The pulses will continue to be an important component of the crop production system. Among the pulses, pigeonpea (*Cajanus cajan* L.) is considered as one of the most important pulse crops of India, which accounts for 90 per cent of the world production, and has got high nutrition value. Seed soaking is one of the pre-sowing seed management techniques for pulses to overcome drought. Pre sowing seed soaking helps in imbibing enough quantity of water and initiating germination quickly. Among the agro-chemicals, growth regulators are widely used in increasing the production of many crop plants. Although, the naturally occurring growth regulators (hormone) normally control plant growth, modification of growth can be achieved by the exogenous application of growth regulators. Few workers have studied the use of seed hardening techniques and foliar sprays of agro-chemicals in different crops. However, the study in this direction on pigeonpea is very meagre. Hence, an attempt has been made to survey the available literature pertaining to increasing productivity potential under receding soil moisture conditions by using seed hardening chemicals and foliar application of agro-chemicals on morpho-physiological parameters, yield and yield components. With this background, an attempt has been made to document the available literature in this chapter.

2.1 Effect of seed hardening chemicals and foliar sprays of agrochemicals on morpho-physiological parameter

Seed hardening has been reported to induce drought resistance in plants and such seeds have the capacity to withstand dehydration and overheating. Other beneficial effects of hardening are inducing better root growth, higher rate of photosynthesis and dry matter accumulation (Henckel, 1964).

Abdel Hafeez and Hudson (1967) reported that in the moist soil & plants from hardened seeds grow better and produce significantly higher dry weight than unhardened plants, irrespective of soil fertility. Seed hardened plants in the least fertile mixture had significantly lower leaf area than unhardened plants in the more fertile soils.

Alikhan and Apparao (1969) found that foliar spray of NAA significantly increased the plant height and stem length and reduced the leaf senescence in greengram.

Studies conducted with finger millet using $CaCl_2$, ascorbic acid, kinetin and benzyl adenine showed a greater beneficial effects in terms of germinability and seedling growth under simulated water conditions or salinity (Krishna sastry *et.al.,* 1969).

Singh and Thakur (1979) reported an improvement in seed germination per cent to the extent of 49, 43, 71, 44 and 47 per cent by pre soaking with water, cobalt (0.1 and 1.0 ppm), molybdenum (1.0 and 2.0 ppm) respectively, over unsoaked seeds in soybean and germination relative index (GRI) to the extent of 108, 67, 26, 92 and 102, respectively over control.

Raffique-Uddin (1984) noticed that foliar spray of CCC at 200, 400, 800 and 1000 ppm concentrations twice or four times during the growing period, significantly reduced the plant height and grain yield was increased by 15 per cent in kidney beans.

There was a significant increase in nitrogen content in leaves and stems of pea plants by spraying cytozyme, NAA and cycocel (Shende *et al.,* 1987).

Arora *et al.* (1988) studied the effect of cytozyme (0.2%) and indicated that it promoted the increase in height of potato plant. The maximum plant height in turnip was noticed with 150 ml/ha of cytozyme.

The plant height was reduced when cytozyme concentration was increased to 200 ml/ha and foliar application of 100 ml/ha miraculan promoted the stem growth of turnip (Rana and Vashistha, 1988).

Arjunan and Srinivasan (1989) indicated that seed hardening treatment with $CaCl_2$ (1.0%) gave significantly higher pod yield in groundnut through increased germination per cent and higher dry matter accumulation.

Srivastava and Sharma (1990) revealed that foliar application of triacontanol (0.01 mg/l) significantly increased the plant height, capsule number, capsule weight, fresh and dry weights of shoot in opium poppy.

Different genotypes of pigeonpea were subjected to water stress at germination, seedling growth emergence and survival stages and the germination per cent, germination relative index and water uptake potential of germinating seeds were reduced by increasing order of water stress in all the genotypes (Singh and Afria, 1990).

Rabi *et al.* (1991) observed that seeds soaked in 100, 250 or 500 ppm cycocel lowered the abscission of buds, flowers and pods by 3.6 - 6.4 and 0.8 - 3.2 per cent in *vicia faba* cv. Giza-1 and Giza-402, respectively as compared to control.

Shah *et al.* (1994) found that foliar application of mixtalol significantly increased plant height, primary branches followed by vipul (triacontanol) in blackgram.

Bioregulators like NAA (10, 20 and 30 ppm), kinetin (10, 20 and 30 ppm) and KNO_3 (100, 200 and 300 ppm) sprayed at bud initiation and pod formation stages of chickpea increased the plant height, number of branches, number of flower buds, number of flowers, vegetative growth and yield. NAA (20 ppm) induced early flowering, whereas, kinetin delayed it slightly (Upadhyay, 1994).

Dashora and Jain (1994) reported that foliar application of triacontanol increased plant height in soybean.

Patel and Saxena (1994) found that soaking greengram and blackgram seeds with NAA solution at a concentration of 10^{-6} M at 25 ^{0}C increased the plant height, number of leaves and number of flowers per plant.

Significantly higher plant height was noticed by Baghel and Yadava (1994) in blackgram with the application of NAA (30 ppm) as compared to control.

Raut *et.al.,* (1995) noticed that foliar spray of biozyme or cytozyme @ 450 ml/ha was relatively more beneficial in increasing plant height and biological yield followed by vipul (triacontanol) and paras (mixtalol) in soybean.

Chikkasubbanna *et al.* (1995) revealed that foliar spray of triacontanol (4 ml/l) increased the plant height, number of branches and plant spread in frenchbean.

Lakshmamma and Rao (1996) reported that NAA spray at 20 ppm increased the dry weight in blackgram.

Maitra *et al.,* (1998) studied the effect of seed soaking treatments with agrochemicals (distilled water, 0.25 % $CaCl_2$, 100 ppm KH_2PO_4 and 100 ppm Na_2HPO_4) on growth and productivity in fingermillet. Treatment with Na_2HPO_4 (100 ppm) caused a remarkable improvement in growth attributes such as plant height and dry matter accumulation at different growth stages.

Kumarvelu *et al.* (2000) studied the effect of triacontanol (0.5 mg dm^{-2}) in greengram and indicated that it promoted the plant height when sprayed at 15 and 20 DAS.

Punithavathi and Palaniswamy (2001) revealed that ragi seeds soaked in 1 per cent concentration of KCl and $CaCl_2$ for Prosopis as well as pungam for 12 hours had higher germination per cent as well as other seed quality parameters like root length, shoot length, vigour index and dry matter production.

Bhattacharya and Sharma (2001) found that leaf area and total dry matter during flowering are major traits to restrict flower drop under normal and late seeding.

Raichur *et al.* (2001) indicated that soaking of seeds with 5-10 ppm of triacontanol followed by 5 ppm foliar spray at 30 DAS increased the seed germination, seedling growth, shoot length and root length in tree species.

Ramarao (2004) noticed an increased pod yield in ICPL 85063 which might be due to higher plant height, RWC, SLA, number of pods per plant, test weight and HI, when evaluated the genotypes of pigeonpea for adaptation to drought under natural condition. The maximum grain yield was obtained with chelated iron (1 kg/ha) + N-P-K-S (20-18-17-20 kg/ha) and this treatment recorded 21.6 per cent increase in yield potential and there was improvement in plant height and number of branches per plant.

Higher gross realization and net profit were recorded with the same treatment followed by $ZnSO_4$ (25 kg/ha) and sodium molybdate (2 kg/ha) in urdbean (Mevada *et al.,* 2005).

Patil *et al.,* (2005) revealed that spraying of NAA (25 ppm) resulted in significantly higher plant height, number of branches per plant as compared to control in mungbean.

Solaimalai and Subburamu (2004) reviewed seed hardening in field crops for improving productivity under rainfed condition. They explained that seed hardening is a practice adopted to make crop plants resistant to soil moisture stress, NaCI, Na_2SO_4, KCl, $MgSO_4$, KH_2PO_4, K_2SO_4, $CaCl_2$, $Na2HP0_4$, nitric acid, succinic acid, auxins, CCC, Jalshakthi, triazoles, cow's urine and cow dung extract are various organic and inorganic seed hardening chemicals. Hardening of seedling resulting from pre-sowing treatment is due to a number of physico-chemical changes within the cytoplasm. Pre-sowing seed hardening with different chemicals improve seed viability as well as vigour, root length, root shoot ratio and yield of rainfed crops.

Patil and Bangal (1985) reported that foliar spray of triacontanol (0.5 ml) to pigeonpea significantly increased the number and weight of seeds per plant.

In another study, pre soaking of bajra seeds in manganese solution (4 %) recorded highest grain yield compared to presoaking of potassium dihydrogen phosphate, diammonium phosphate, potassium chloride, ferrous sulphate and zinc sulphate (Kannadasan *et. al.*, 1985).

Rangaswamy *et.al.* (1993) found that seed hardening with $CaCl_2$ (0.4%) and CCC (0.2%) increased the germination per cent, vigour index and root: shoot ratio in sorghum, pigeonpea, groundnut and cowpea.

Nayyar and Malik (1993) revealed that mixtalol (triacontanol based) treated seeds performed better than water treated or untreated seeds in terms of germination percent, vigour index, germination relative index, mean length of roots and shoots and seedling dry weight under drought stress conditions

Prabhu (2000) observed that foliar spray of NAA (40 ppm) and miraculan (2000 ppm) followed by of miraculan (1000 ppm) were effective in increasing seed yield over other treatments in black gram.

Foliar application of NAA (50 ppm) significantly increased the plant height, number of leaves and branches per plant compared to control in soybean (Thakare *et al.,* 2006).

Nehare *et al.* (2006) reported that foliar application of NAA (20 ppm) significantly increased the plant height, test weight, biological yield and B:C ratio compared to control, Triacontanol and ethephon in fenugreek.

Pothalkar and Nawalagatt (2007) found that application of miraculan (2.0 ml/l) followed by NAA (40 ppm) and NAA (20 ppm) was found more beneficial and significantly improved all the morpho-physiological traits, growth parameters, biochemical constituents and yield and yield components during both the years in pigeonpea.

Reddy *et al.* (2009) reported that drought management practices significantly influenced the yield attributes, yield and net returns in pigeonpea. Significantly higher yield and net returns were observed with application of RDF along with seed soaking of pigeonpea before sowing for 2 h with KH_2PO_4 or $CaCl_2$ during both years. There was no significant difference between foliar fertilizer application of 2% urea and 2% KCl in producing yield.

Selvi *et al.* (2009) conducted experiment during *kharif* 2004-2005 in rainfed conditions on red soil to study the effect of different drought management practices such as application of FYM in soil, seed coating with 2% solution of $CaCl_2$ or KH_2PO_4 foliar spray of 2 % urea, 2 % KCl at flowering in redgram variety, Application of recommended dose of fertilizer (RDF) + cultural mulch two times records the maximum yield of 568 kg/ha and 557 kg/ha during 2004 and 2005 respectively. This was comparable to application of RDF alone. The net profit and BCR were Rs.4060/ha; 1.5 and Rs.4015; 1.61 during 2004 and 2005 respectively.

Tripathi *et al*. (2009) reported that spraying of TIBA (2, 3, 5-triiodobenzoic acid, 25 mg and 50 mg l^{-1}), and NAA (naphthalene acetic acid, 25 mg and 50 mg l^{-1}) increased flowering, number of pods plant^{-1}, number of seeds pod^{-1} and 1000-seed weight during both the seasons. It also increased seed yield and harvest index of pigeonpea by 20.9% and 25.0% over control, respectively.

Dhanoji (2011) revealed that seeds soaked for two hours at ratio of 1:1, (seed: solution) recorded significant improvement in seedling establishment, early emergence (54%) and uniform germination (96%), as compared to control (34% and 83%). Significantly higher dry weight of the seedling, leaf size (leaf length and width) shoot length and root length was recorded with two hours of soaking at 1:1 ratio (seed to solution) as compared to control.

2.2 Effect of seed hardening chemicals and foliar sprays of agrochemicals on growth parameters

The technique of growth analysis has been extensively used for better understanding of the physiological basis of yield variation in crop plants.

Growth analysis is a physiological probe on the development of the crop in a chronological sequence to elucidate and account the causes for differences in yield through the events that have occurred at different stages of growth.

Extensive studies have been made on the physiological analysis of growth parameters in cereals, pulses and oilseeds emphasizing their importance in yield analysis (Chhonkar and Singh, 1959).

Thirumalaiswamy and Rao (1977) reported that seed treatment with distilled water, CCC (5 ppm) and kinetin (5 ppm) and moisture levels slightly increased net assimilation rate (NAR), relative growth rate (RGR) and leaf area in pearl millet and irrespective of moisture levels, the size of the leaf was greatly influenced by cycocel followed by kinetin.

Kalubarme and Pandey (1979) showed that specific leaf weight (SLW) is a stable character and was initially low and improved subsequently and reached the maximum value at 42 days in greengram genotypes . Crop productivity is mainly determined by crop growth rate (CGR) which depends on leaf area index (LAI) and the rate of photosynthesis. The CGR was found to be less during early vegetative stage but increased with the advancement of growth in greengram. They further reported that NAR and RGR decreased with the advancement of crop growth.

Nijhawan and Chandra (1980) observed wide variations in leaf area among different mung bean varieties and higher leaf area duration (LAD) during bud initiation stage was found to be obligatory for better yield.

Misra and Dwivedi (1980) found that ragi seeds treated with potassium and distilled water produced significantly higher leaf area and dry weight of shoot compared to control.

De *et al*. (1982) noticed that in wheat, seed soaking with cycocel decreases the shoot growth and leaf area per plant progressively with increase in concentrations of the chemical by 10, 40 and 80 mg/l. The radicle growth was increased considerably.

Pre sowing seed hardening of ragi seeds in different chemical solutions significantly increased the germination, root growth and dry matter production (Karivaratharaju and Ramakrishna, 1985).

Bhatia and Rathore (1986) studied the effect of seed soaking treatments with distilled water, KH_2PO_4 (5%), $CaCl_2$ (0.25%), cycocel (0.1%), NaCl (2.5%) and saturated solutions Ca $(OH)_2$ on germination and seedling attributes in wheat. They found that treatment with KH_2PO_4 enhanced the germination and increased the number of seedlings per meter row length. Dry matter accumulation and seedling height was increased by KH_2PO_4 followed by distilled water and both were significantly superior over control.

Similarly, seed treatment with $CaCl_2$ (2%) in the ratio 1:1 (seed: solution) for four hours increased drought resistance in sorghum. There was an improvement in the germination, seedling growth and development, higher relative water content (RWC) and root : shoot ratio (Patil, 1987).

Sumabai *et al*. (1987) indicated that foliar spray of ascorbic acid, NAA and GA recorded increased assimilate production and favoured longer reproductive growth and there was increase in LAI, LAD and NAR in greengram.

There is a significant increase in fresh and dry weights of shoot with the foliar application of triacontanol (0.01 mg/l) in opium poppy (Srivastava and Sharma, 1990).

Eshanna and Kulkarni (1990) revealed that seed treatment with $CaCl_2$ in the ratio of 1:1 (seed : solution) recorded significantly higher plant height, LAI, CGR, NAR and total dry matter at different growth stages in maize as compared to control.

Seed hardening with cycocel generally increased root, stem and total dry weight, RGR, NAR and leaf weight ratios in wheat as compared to control (Gurudev Singh *et. al.,* 1991).

Nawalagatti *et al.* (1991) found that foliar spray of CCC at 1000 ppm increased the LAI, LAD, NAR, CGR and total dry matter production followed by cytozyme and CCC at 1000 and 500 ppm in groundnut.

Dashora and Jain (1994) also indicated that spraying of triacontanol significantly increased LAI by 27.9 per cent in soybean.

Deotale *et al*. (1994) found a significant increase in leaf area with the application of triacontanol in groundnut and it increased with an increase in dose of triacontanol (0 to 50 ppm).

Shindhe and Jhadav (1995) found that foliar application of NAA (20 ppm) at flowering stage gave higher values for leaf area and SLW in cowpea.

Bhagat *et al*. (1995) noticed that the foliar application of NAA (40 ppm) at flower initiation stage significantly increased the CGR at pod filling stage in blackgram.

There is increased dry matter accumulation by foliar spray of NAA at 20 ppm in blackgram (Lakshmamma and Rao, 1996).

Jayarami Reddy et.al, (1996) reported that foliar spray of NAA (10 ppm) + KNO_3 (0.5%) and NAA (20 ppm) + KNO_3 (0.5%) recorded the maximum dry matter production in pigeonpea as compared to control.

Nargis Jahan *et al.* (1997) observed that foliar application of triacontanol (2.5 ppm) increased the leaf and stem dry weights in okra.

Maitra *et al.* (1998) studied the effect of seed soaking treatments with agro-chemicals (distilled water, 0.25% $CaCl_2$, 100 ppm KH_2PO_4 and 100 ppm Na_2HPO_4) on growth in fingermillet and found that the treatment with Na_2HPO_4 (100 ppm) caused a remarkable improvement in growth attributes such as LAI, LAD, CGR and dry matter accumulation at different growth stages.

Govindan and Thirumurugan (2000) revealed that the growth parameters viz., LAI and dry matter production in greengram were significantly higher with the foliar spray of KNO_3 (1%) or KCl (1%) and their combination.

Punithavathi and Palaniswamy (2001) indicated that ragi seeds soaked in 1% concentration of KCl and $CaCl_2$, for 12 hours recorded higher germination per cent as well as root length, shoot length, vigour index and dry matter production.

Raichur *et al.* (2001) found that soaking of seeds in 5-10 ppm triacontanol followed by 5 ppm spray at 30 DAS increased the seedling growth, shoot length, root length in tree species.

The foliar application of triacontanol (0.2 %) at vegetative, flowering and poding stages significantly increased the biomass production and better dry matter partitioning towards the sink in mungbean (Jayaramireddy *et al.,* 2002).

Sinha *et al.,* (2002) found that ascorbic acid treated moong and pea plants showed an increase in the nodule number and dry weight of the plants as compared to the control.

Prakash *et al*., (2003) reported that combined foliar application of planofix (30 ppm) at 30 and 45 DAS and chamatkar (120 ppm) at 60 DAS recorded higher LAI and SLW in blackgram.

Sumeria (2003), the application of 60 kg P/ha and triacontanol granules at 30 kg/ha significantly increased growth parameters in mustard.

Patil *et al.* (2005) noticed that spraying of NAA (25 ppm) recorded significantly higher flower production and clusters per plant and total dry matter in mungbean.

2.3 Effect of seed hardening chemicals and foliar sprays of agrochemicals on yield and yield components

Appleby *et al.* (1966) revealed that grain yield is the ultimate economic product of the crop, which is determined mainly by grain weight and number of grains per unit land area. Most of the yield components show direct influence on grain yield and an increase in test weight and grain yield of wheat with 5 per cent with cycocel seed treatment.

Austin *et al.* (1969) noticed that plants from hardened seeds of carrot gave the mean root yields of 64.0 t/ha compared to 59.2 /ha from untreated seeds. Woodruff (1969) indicated that pre sowing seed hardening increased the grain yield in wheat by 20 per cent.

Rajashekhar *et al*. (1970) reported that with the use of hardened ragi seeds, there was an increase in the yield (an average 12%) as compared to unhardened seeds. Hardened seeds responded better to fertilizers.

Filatov and Frolova (1975) found that hardening induced heat tolerance in sunflower and the hardened plants produced more seed yield from 150 to 300 kg/ha, which was more than unhardened plants. The increase in yield was due to high photosynthetic rate.

Pre sowing seed hardening treatment increased early emergence by 13 per cent and yield by 60 per cent in carrot, while in lettuce, the emergence was increased by 9 - 11 per cent and yield by 10 - 12 per cent (Pantielev *et al.* 1976).

Karnail Singh (1976) reported that seed cotton yield increased significantly with the application of cycocel @ 80g ai/ha at 40 DAS over control.

Misra and Dwivedi (1980) reported that seed treatment with potassium and distilled water distinctly produced more grain and straw yields as compared to control in wheat.

Foliar application of miraculan at 60 days after sowing increased grain yield per plant significantly with 0.5 and 1.0 per cent treatment and was due to combined effect of increase in grain size and pod number in pigeonpea (Bangal *et al*., 1984).

Sidhu *et al*. (1980) concluded that the foliar spray of $ZnSO_4$ (0.5%) recorded maximum fruit weight and yield over other treatments in peech.

Das and Sarkar (1981) revealed that post flowering foliar spray with KNO_3 (0.5 %) solution gave higher yield of both grain and straw in rice and wheat.

Dighe *et al.* (1983) opined that among the different methods of cycocel treatments, the seed treatment and foliar spray of cycocel produced higher grain yield in wheat than the application of cycocel through soil drenching.

Sen and Misra (1984) indicated that seed treatment with $CaCl_2$ (0.25 %) prolonged the grain filling period in wheat by way of early ear head emergence and consequently increased the grain yield. Foliar spray of CCC at concentrations of 0, 200, 400, 800 and 1000 ppm twice or four times during the growing period significantly increased grain yield by 15 per cent in both the cultivars of kidney beans.

In another study, pre soaking of bajra seeds in manganese solution (4 %) recorded highest grain yield compared to pre soaking of potassium dihydrogen phosphate, diammonium phosphate, potassium chloride, ferrous sulphate and zinc sulphate (Kannadasan *et al*., 1985).

Masood Ali (1985) indicated that foliar spray of KCl (2%) solution significantly increased the grain yield over water spray in chickpea.

Goswami and Garg (1985) observed that the application of ascorbic acid increased the fodder yield by 42 to 50 per cent in lucerne. Foliar application of potassium: K_2SO_4 (1 %) and KCl (1 %) increased the seed yield by 21.2 and 33.4 per cent, respectively over control in blackgram (Chandrababu *et al.,* 1985).

Sen and Misra (1987) reported that treating wheat seeds $CaCl_2$ (0.25 %) or KCl (2.5 %) increased the grain yield as compared to control .

Patil (1987) opined that seed treatment with $CaCl_2$ (2 %) for four hours increased the drought resistance in sorghum and also increased grain yield by 10 per cent over control under dry land conditions.

Jain *et al.* (1987) reported that foliar spray of triacontanol (0.1 ppm) gave significantly higher number of pods per plant, yield per plant and test weight followed by seed dressing of triacontanol (1 ppm) in soybean and groundnut.

Rana and Vashista (1988) reported that there was an increase in the weight of tubers per plant with the foliar application of miraculan or cytozyme at 100 ml/ha in potato.

Sharma *et al.,* (1989) stated that foliar spray of NAA improved yield and its components significantly over control in mungbean.

Sharma *et al*. (1990) indicated that foliar spray of biozyme increased the yield by increasing the number of pods per plant, number of seeds per pod and 100 seed weight followed by paras and atonik in soybean.

Srivastava and Sharma (1990) found that capsule number, capsule weight and dry weight of the shoot were significantly higher with foliar application of triacontanol (0.01 mg/l) in opium poppy.

Foliar spray of green gram with K_2SO_4 (1%) and KCl (1%) significantly increased the seed yield by 10.1 and 7.7 per cent, respectively over control (Sadasivam *et al.,* 1990).

Sarkar and Mukhopadhyay (1990) reported that foliar spray of 0.5 per cent KNO_3 solution at 50 per cent flowering stage significantly increased the grain yield of high yielding and traditional cultivars by 49.1 and 19.3 per cent, respectively over control in rice.

Khalate *et al.* (1990) reported an increase in the yield of onion due to the spray of $ZnSO_4$ (0.5 and 1%), $CuSO_4$ (1%) and $MnSO_4$ (0.6%).

Shindhe *et al*. (1991) observed that foliar spray of growth regulators (NAA and ethrel) and KNO_3 in cowpea increased the pod yield per plant, weight of individual pod and ultimately resulted in elevating the seed yield by 33 per cent.

Foliar spray of vipul (2.5 ppm) in rainy season increased total number of fruits per plant in okra (Pandita *et al.,* 1991).

Singh *et al.* (1991) found that foliar spray at pre flowering stage with cycocel (15 mg/l), mixtalol (6 mg/l) and triacontanol (4 mg/l) effectively enhanced the seed yield and protein content by their ameliorative effects on flower retention, pod formation, seed setting and seed weight in chickpea.

Nawalagatti *et al.* (1991) reported that foliar spray of CCC (1000 ppm) increased total dry matter production and pod yield followed by cytozyme (1000 and 500 ppm), respectively in groundnut.

Shanmugasundaram and Nanjan (1992) indicated that soil application of magnesium (60 kg/ha) and foliar spray of magnesium sulphate (1.0%) recorded maximum potato tuber yield compared to control.

Spraying of NAA and miraculan at flower initiation and seed filling stages also increased the seed yield in greengram and blackgram (Chaplot *et al.* 1992).

Rao and Khanna (1992) indicated no significant effect on days to 75 per cent heading and maturity in triticale due to the application of mixtalol; but increased number of tillers per plant, 100 grain weight and yield per hectare were noticed as compared to control.

Subramanian and Janardhan (1992) reported that triacontanol (2 ml/l) as a seed soaking medium improved both seed germination as well as seedling growth, fresh and dry weights and finally yield in pigeonpea, cowpea and soybean.

The application of zinc significantly increased the seed yield as compared to control in urdbean (Kushwaha, 1993).

According to Nayyar and Malik (1993), mixtalol treated seeds performed better as compared to water treated or untreated seeds in terms of mean length of shoots and dry matter accumulation and yield under drought stress contion.

Foliar application of mixtalol significantly increased the dry matter per plant and yield followed by vipul in blackgram (Shah *et al.,* 1994).

Dashor and Jain (1994) reported highest yield response by the foliar application of triacontanol followed by kinetin in soybean.

Shinde and Jadhav (1995) reported increased pods per plant, seeds per pod and finally grain yield in pigeonpea due to the foliar application of NAA (40 ppm).

The application of $FeSO_4$ and $ZnSO_4$ individually showed significant increase of seed yield in soybean (Bhanavase *et al.,* 1994).

Upadhyay (1994) reported significant increase in the yield of chickpea due to foliar application of both NAA, kinetin (10, 20,30 ppm) and KNO_3 (100,200,300 ppm) at both bud initiation and pod formation stages.

Amaregouda *et al.* (1994) observed that seed treatment with $CaCl_2$ (2%) gave higher yield by 19% in wheat as compared to control.

Puste and Kundu (1995) observed that foliar spray of paras (triacontanol) at 5 ml/l tends to increase tuber yield over control.

Foliar spray of biozyme or cytozyme (450 ml/ha) was relatively more beneficial in increasing biological yield, harvest index, 100 - seed weight and seed yield followed by vipul (triacontanol) and paras (mixtalol) in soybean (Raut *et al.* 1995).

According to Bana *et al.* (1996), foliar spray of mixtalol (4 ppm) at 60 DAS was found to be effective in increasing grain yield in soybean.

Lourduraj *et al.* (1996) reported that among different seed treatment methods, seed treatment with $CaCl_2$ recorded higher dry pod yield, shelling per cent, 100 kernal weight and finally yield in groundnut.

Double sprays of NAA and triacontanol individually increased the number of pods per plant, pod weight and finally, the seed yield in soybean over control (Shukla *et al.,* 1997).

Chougale (1997) indicated that miraculan and cytozyme are known to affect various physiological traits and increased the yield potential of sesamum.

Christopher *et al.* (1997) found that the foliar application $FeSO_4$ (0.1%) at 45 DAS resulted in highest dry pod yield, shelling per cent and test weight in groundnut.

Nargisjahan *et al.* (1997) opined that the foliar application of triacontanol is effective in increasing number of fruits per plant and fruit yield in okra.

Shukla *et al.* (1997) indicated that double sprays of triacontanol enhanced the biomass, pod weight per plant and ultimately resulting in enhanced seed yield.

Prakasa Rao and Narayanan (1997) noticed that foliar spray of NAA (20 ppm) enhanced number of pods per plant and reduced the flower drop to an extent of 15 per cent and resulted in an increased seed yield by 23 per cent over control in pigeonpea.

Pujari *et al.* (1998) studied the foliar application of urea and triacontanol and reported a significant increase in seed yield of pigeonpea.

Rao *et al.* (2000) conducted experiment on sorghum during 1996 and 1997 and observed increased grain yield of 32 and 27 per cent, respectively over control due to the application of KCl (1%) at terminal drought stress.

Jirali (2001) indicated that the application of cytozyme (2000 ppm) and miraculan (2000 ppm) was found to be very effective and improved all the important morpho-physiological, yield and yield attributes in turmeric.

The higher fodder productivity was observed in seed hardening with K_2HPO_4 (2%) followed by KCl (2%) and KH_2PO_4 (2%) in forage grasses (Swaminathan and Sujata, 2001).

Jayarami Reddy *et al.* (2002) revealed that the foliar application of triacontanol (0.2%) at vegetative, flowering and poding stages significantly increased seed yield in mungbean grown under rained condition.

Upadhyay (2002) noticed that foliar spray of NAA (20 ppm) resulted in significantly higher number of flowers per plant, pod length, grain number per pod, number of pods per plant, biological yield and grain yield.

Garai and Datta (2003) found that nodules per plant and yield increased due to foliar application of cycocel in greengram.

Kalpana and Krishnarajan (2003) reported increased number of pods per plant, number of filled seeds per pod, total number of seeds per pod, seed filling percentage, test weight and yield in soybean due to the foliar application of NAA (40 ppm).

Ramesh (2004) indicated increased number of pods per plant, pod yield per plant, seed yield per plant, 100 seed weight and HI due to seed hardening with $CaCl_2$ (2%) in chickpea. Foliar application of $ZnSO_4$ (0.5%) significantly increased seed yield and its attributes over other treatments in pigeonpea (Varma *et al.,* 2004).

Thakare *et al.* (2006) opined that foliar application of NAA (50 ppm) will result in significantly higher yield contributing parameters viz., number and dry weight of pods per plant, 100 seed weight, seed yield per hectare in soybean. Similarly, foliar application of NAA (20 ppm) resulted in significantly higher number of pods per plant, seeds per pod, test weight, seed yield, straw yield, biological yield, HI and B:C ratio in fenugreek as compared to control.

CHAPTER III
MATERIAL AND METHODS

The present investigation was carried out to determine the effect of seed hardening, use of agro chemicals and nutrients on terminal flower drop and drought tolerance in pigeonpea. The experimental materials used and the methods applied during the course of present investigation have been described below.

3.1 Experimental site

The experiment was conducted at Experimental field of AICRP (All India Coordinated Research Project) on Pigeonpea, R.A.K. College of Agriculture; Sehore (M.P.). The field was fairly uniform with gentle slope, adequate drainage and normal fertility status. The purpose of this experiment was to find out the effect of seed hardening and use of agro-chemicals/nutrients on terminal flower drop and drought tolerance mechanisms to improve productivity potential under rainfed condition in pigeonpea. The details of the experiment are described below.

3.2. Experimental soil

The experimental field consist clay loam Vertisol with 52 % clay, 41.3 % salt and 6.6 % sand with pH ranging from 7.2 to 7.8. The soil was low in available nitrogen, medium in available phosphorus and high in available potassium.

3.3 Climatic conditions

Sehore is situated at the latitude of 23°12´N, 77°05’ E longitude and an altitude of 498.7 meter above the mean sea level. It lies in the western track of Vindhyan plateau agro climatic zone of Madhya Pradesh and enjoy sub tropical climate. The annual rainfall varies from 1000-1250 mm with major precipitation in the month of July and August.

The meteorological data during the crop growth period (2013-14). The total rainfall during 2013-14 was 1389.2 mm. The maximum temperature during crop growth period ranged from 33.7.0 ^{0}C (September) during 2013-14. The minimum temperature during 2013-14 ranged from 7.74 ^{0}C (December).

The maximum relative humidity ranged from 55.71 per cent (December) to 68.07 per cent (September).

Table 3.1 Monthly meteorological data during crop growth period 2013-14

Standard Week	Standard week	Rainfall (mm)	Temperature		Average	Humidity
			Max.	Min		
25 June -1 July	26	312.2	28.1	23.1	25.6	65.14
2-8 July	27	82	27.7	22.7	25.2	64.71
9-15 July	28	120.5	28.4	23.6	26.0	65.50
16-22 July	29	85.0	26.7	23.4	25.0	64.57
23-29 July	30	176.5	27.4	23.1	25.2	55.93
30 July -5 Aug.	31	120.0	26.9	23.0	25.0	64.50
6-12 Aug.	32	37.0	26.6	22.8	24.7	64.29
13-19 Aug.	33	33.5	28.2	23.2	25.7	65.36
20-26 Aug.	34	287.5	26.3	22.8	24.5	64.00
27 Aug - 2 Sept.	35	4.0	28.5	21.9	25.2	64.71
3-9 Sept.	36	2.0	30.5	21.4	25.9	65.43
10-16 Sept.	37	0.0	33.7	23.2	28.5	68.07
17—23 Sept	38	111.5	31.9	22.6	27.3	66.71
24-30 Sept.	39	0.5	29.2	21.5	25.4	65.07
1-7 Oct.	40	9.0	27.9	22.0	25.0	64.50
8-14 Oct.	41	8.0	30.0	21.3	25.6	65.14
15-21 Oct.	42	0.0	31.9	18.7	25.3	64.86
22-28 Oct.	43	0.0	30.2	17.1	23.6	63.14
29 Oct. -4 Nov.	44	0.0	30.1	16.44	23.27	62.71
5-11 Nov.	45	0.0	28.09	16.16	22.12	61.71
12-18 Nov.	46	0.0	25.49	10.63	18.06	57.64
19-25 Nov.	47	0.0	26.80	10.39	18.59	58.29
26 Nov.-2 Dec.	48	0.0	26.99	10.81	18.90	58.5
3-9 Dec.	49	0.0	25.61	10.89	18.25	57.71
10-16 Dec.	50	0.0	24.46	7.74	16.1	55.71
17-23 Dec.	51	0.0	23.30	8.16	15.73	56.79
24-31 Dec.	52	0.0	22.14	11.81	16.98	56.81
1-7 Jan.	53	0.0	22.91	12.39	17.65	57.14
8-14 Jan.	54	0.0	21.77	10.94	16.36	55.93
Total		**1389.2**				

3.4 Experimental details

Treatments

T_1: Seed hardening with $CaCl_2$ (2%)

T_2: Seed hardening with $CaCl_2$ (4%)

T_3: Seed hardening with KCl (100 ppm)

T_4: Seed hardening with KCl (200 ppm)

T_5: Foliar application of NAA (20 ppm) at flowering and pod set

T_6: Foliar application of NAA (40 ppm) at flowering and pod set

T_7: Foliar application of Triacontanol (20 ppm) at flowering and pod set

T_8: Foliar application of Triacontanol (40 ppm) at flowering and pod set

T_9: Control

Design	:	Randomized Complete Block Design
Fertilizer application	:	25:50 N: P_2O_5 kg/ha
Treatment	:	9 (including control)
Genotypes	:	1 (JKM-189)
Plot size	:	14.4 m2
Date of sowing	:	25-06-2013
Replications	:	03
Row length (m)	:	04
Row to row spacing (cm)	:	60
Plant to plant spacing (cm)	:	20
Row per plot	:	06

The recommended dose of nitrogen and phosphorous per hectare was applied in the form of DAP (Di Ammonium Phosphate), at the sowing time.

3.5 Cultural operations

3. 5.1. Land preparation

Land was prepared by deep summer ploughing, followed by clod crushing and repeated harrowing. The land was smoothened with a plank to bring the soil to a fine tilth suitable for sowing.

3. 5.2. Seed treatment and sowing

A day before sowing the seeds of JKM-189 were soaked separately in $CaCl_2$ (2% and 4%) and KCl (100 and 200 ppm) for six hours. The seeds were dried under shade and used for sowing.

3. 5.3. Treatment imposition

Foliar application of plant growth regulators NAA and Triacontanol at the concentrations of 20 & 40 ppm were applied at flowering and pod initiation stage..

3.5.4. Harvesting

Plants were harvested in each experiment as per the treatment in each plot by cutting the plants close to the ground. Harvested crop was allowed to dry in the threshing yard. After complete sun drying, the crop was threshed by beating with wooden sticks. The seeds were winnowed, cleaned and seed weight of net plot was recorded, from which the grain yield was computed.

3.6 Collection of experimental data

Ten plants at random from each plot were selected and tagged for the purpose of recording morphological, physiological and yield parameters at different stages of crop growth.

3.6.1 Morphological observation

3.6.1.1 Plant height (cm)

Plant height was recorded at 45, 90 120 Days after sowing and at harvest from the ground level to shoot tip. Measurements were taken from ten tagged plants in each treatment and the average height was calculated which is expressed in centimeters.

3.6.1.2. Days to flower initiation

Number of days required from sowing to the appearance of the first flower bud in each treatment was computed and expressed as days to flower initiation.

3.6.1.3. Flower shedding

The Number of flower dropped was counted per day in individual treatment and it is expressed in number of flowers dropped per plant per day at 10 and 20 days after flowering.

3.6.1.4. Days to pod initiation

The number of days from sowing to first pod initiation was recorded in individual treatment and expressed as days required for pod initiation.

3.6.2 Physiological parameters

3.6.2.1. Relative leaf water content (RLWC)

The relative content was estimated by the method of Barrs and Weatherly (1962). Ten leaf discs were collected randomly in each treatment and weighed accurately upto third decimal on a single pan analytical balance. This was considered as fresh weight. The weighed leaf discs were allowed to float on distilled water in a Petridish and allowed to absorb water for four hours. After four hours, the leaf discs were taken out and their surface was blotted gently and weighed. This was referred to as turgid weight. After drying in hot air oven at 720 C for 48 hours, the dry weight was recorded and RLWC was calculated by using the following formula.

$$\text{RLWC (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.6.2.2 Drought tolerant efficiency (%)

$$\text{DTE (\%)} = \frac{\text{Yield under stress (control)}}{\text{Yield under non stress (treatment)}} \times 100$$

3.6.2.3. Drought susceptibility index (%)

DSI = $(1-Y_d/Y_p)/D$

Where, Y_d = grain yield of treatment under stress condition

Y_p= grain yield of the treatment under non stress condition

D = (1-Yr/Yi)

Y_r= mean of all the treatments under stress

Y_i= mean of all the treatment under non stress

3.6.2.4. Rate of water loss (mg/min)

Randomly selected ten plant samples were separated and dried in oven at 50°C until obtained different weight per hours and plants dried for 5 to 6 hours and calculate the rate of water loss in mg/min.

3.6.3 Yield and yield components

3.6.3.1. Number of pods per plant

The number of pods from ten tagged plants was counted and the average was worked out.

3.6.3.2. Per cent pod set

The per cent of pod set was taken as the ratio of total number of pods to the total number of flowers produced. It was calculated as per the formula given below and expressed in per cent.

$$\text{Per cent pod set} = \frac{\text{Total number of pods}}{\text{Total number of flowers}} \times 100$$

3.6.3.3. Seed yield (g/plant)

Seeds were separated from the pods of each of ten sample plants and were weighed and averaged as seed yield per plant.

3.6.3.4. Total dry matter production (g/plant)

Randomly selected ten plant samples were separated and the dry weight of plant along with pods was recorded after cutting root portion for each treatment in grams per plant.

3.6.3.5. Harvest index

Harvest index was calculated by using the formula of Donald (1962) and expressed in per cent.

$$HI\ (\%) = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

3.7 Statistical analysis

The model for experimental design used in randomized block design can be expressed as follows.

Pij= μ+ gi+ rj + eij

Where,

Pij = phenotypic effect of ith genotype in the jth replication.

μ = general population mean

gi = effect of ith genotype.

rj = effect of jth replication.

eij= error associated with the experiment.

Table 3.2 The skeleton for analysis of variance for randomized complete block design

Source of variation	**DF**	**Sum of squares**	**Mean sum of squares**
Replication	(r-1)	SSr	$\sigma^2 r$
Treatments	(t-1)	SSg	$\sigma^2 e + r\sigma^2 g$
Error	(r-1) (t-1)	SSe	$\sigma^2 e$
Total	(rt-1)		

Where,

r = number of replications

t = number of treatments.

$\sigma^2 t$ = genotypic variance

$\sigma^2 e$ = error variance

3.7.1. Test of significance

The mean sum of squares for genotypes and replications were tested against the error mean sum of squares for calculating F values which were compared with tabulated F value at 5 and 1 percent level of significance.

3.7.1.1 Mean

Mean was calculated using following conventional formula

$$\bar{X} = \frac{\Sigma X}{N}$$

Where,

$\bar{X}$= simple mean

ΣX = summation of all the observation

N = number of observation

3.7.1.2 Range:

It is the range of lowest and highest values of each trait taken in the observations.

3.7.1.3. Standard error of mean.

It was calculated as formula given below.

$$\textbf{SEm}\pm = \sqrt{MSe/r}$$

Where,

SE m± = standard error of mean

MSe = mean sum of square due to error

r = number of replication.

3.7.1.4. Standard error of differences.

It was calculated as formula given below

$$\textbf{SEd}\pm = \sqrt{2MSe/r}$$

Where,

SEd± = standard error of differences.

Mse = mean sum of square due to error.

r = number of replications.

3.7.1.5. Critical difference:

It was measured as formula mentioned below.

CD = SEd X t value at 5% level of significance.

Where,

CD= critical difference

SEd = standard error of difference

t = table value at 5 % probability level of error df.

CHAPTER IV

RESULTS

The present investigation entitled, "Evaluation of plant growth regulators and seed primers for drought tolerance in pigeonpea (*Cajanus cajan*(L.) Millsp.)'' was conducted during *kharif* 2013 at experimental field of AICRP-Pigeonpea, Rafi Ahamad Kidevai College of Agriculture, Sehore (M.P.). The major aim of this study was to evaluate theeffect of plant growth regulators and seed hardening treatments on morphological, physiological and yield characters in pigeonpea. The results obtained from the investigation are presented as under.

4.1 Analysis of variance

The mean performance of genotype (JKM 189)in response to various treatments for each character studied was analyzed statistically using randomized complete block design (RCBD). Highly significant ($P<0.01$) difference between the treatments for all the characters except for plant height at 45 and 90 DAS (Days after sowing) (Table 4.1 and 4.2) were observed. The difference for various treatments indicated that there was significant effect of difference plant growth regulators and seed hardening treatments on various morphological, physiological and yield parameters in pigeonpea.

4.2 Morphological Characters

4.2.1 Plant height (cm)

The data on plant height as influenced by seed hardening chemicals and growth regulators showed significant differences among the treatments for plant height at 120 days after sowing (DAS) and at harvest (Table 4.1) while there was no-significant difference among the treatments for plant height at 45 and 90 DAS. The effect of plant growth regulators on plant height was more as compared to seed hardening treatments. The average plant height of treatments of plant growth regulators (162.93 cm) was greaterthan seed hardening chemicals (158.19 cm) (Table4.3).Among plant growth regulators, the treatment with NAA 40 ppm registered significantly higher plant height (147.47 & 164.80 cm) which was at par with NAA 20 ppm, at 120 DAS and at harvest.The plant height in control was consistently less at different stages of plant growth as compared to different treatments applied.

4.2.2 Days to flower initiation

The number of days to flower initiation as influenced by plant growth regulators and seed hardening chemicals showed significant differences among the treatments (Table 4.1). Days to flower initiation in different treatments ranged from 118-127 days. In general, seed hardening chemicals took lesser days to flower initiation (121.42 Days) compared to plant growth regulators (126 Days) as well as control. Among seed hardening chemicals, the treatment with $CaCl_2$ 2 %was superior with lesser number of days to flower initiation (118 days) followed by $CaCl_2$ 4% (120.67 Days), and KCl 100 ppm (123 Days). Among the plant growth regulators, the treatment NAA 20 ppm recorded lesser number of days to flower initiation (125 Days) followed by NAA 40 ppm (126 Days), while the maximum number of days to flower initiation (127 days) was recorded in triacontanol 20 ppm which was at par with triacontanol 40 ppm (126 days) (Table 4.3 and fig 4.2).

4.2.3 Flower shedding

The results of data obtained on flower shedding revealed that there was significant difference between treatments for number of flowers dropped at 10 and 20 days after flowering indicating significant influence of plant growth regulators and seed hardening chemicals on reducing rate of flower shedding (Table 4.3). At 10 days after flowering, the average flower shedding in seed hardening treatments (200.26) was lesser than plant growth regulators (251.15). The minimum flower shedding was recorded in KCl 200 ppm (182.73) which was at par with $CaCl_2$ 4% (184.37) and $CaCl_2$ 2% (210.12) while the maximum flower shedding was noticed in control (322.28). Among plant growth regulators, the minimum flower shedding noticed in triacontanol 40 ppm (241.33) which was at par with triacontanol 20 ppm (245.10) and NAA 40 ppm (251.41). The highest percent reduction in flower drop (43.3 %) was recorded in KCl 200 ppm followed by $CaCl_2$ 4% (42.79%) and $CaCl_2$ 2% (34.08%).

At 20 days after flowering, the minimum flower shedding was recorded in $CaCl_2$ 4 % (353.04) which was at par with KCl 200 ppm (366.40) while among the plant growth regulators, the minimum flower shedding was noticed in triacontanol 40 ppm (370.67) which was at par with triacontanol 20 ppm (403.10) whereas the maximum number of flower dropped in control (671.94) (Table 4.3). The highest percent reduction in flower drop (47.46 %) was recorded in $CaCl_2$ 4 % followed by $CaCl_2$ 2% (37.72%) and KCl 200 ppm (45.47%) (Table 4.3 and Fig 4.4).

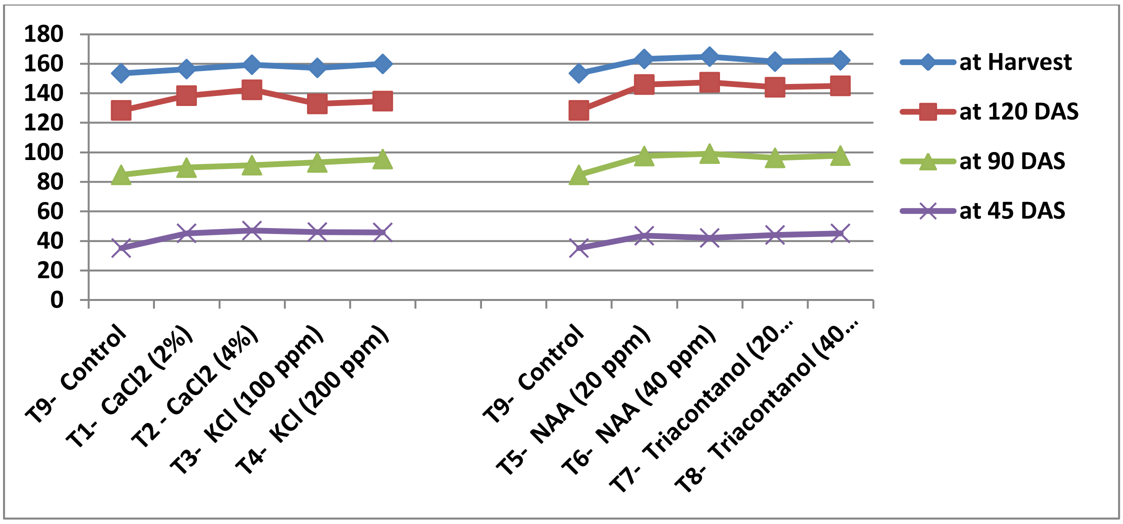

Figure 4.1 Plant height at various stages of plant growth in response to seed priming and plant growth regulators.

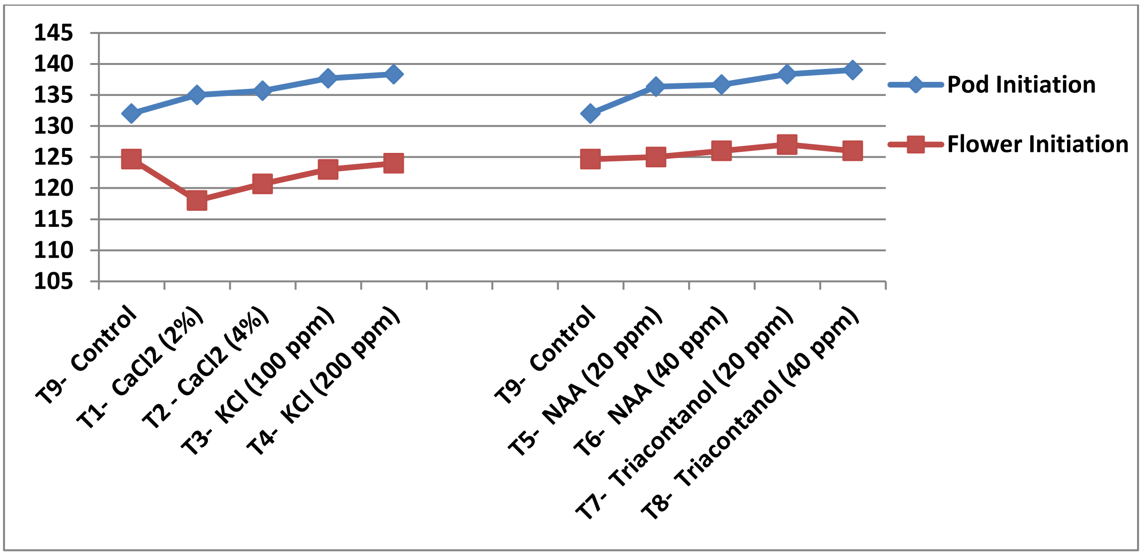

Figure 4.2 Day to flower and pod initiation in as influenced by seed priming and plant growth regulators.

Table 4.1 Mean sum of squares for morpho–physiological and yield traits.

Source of variation	DF	Plant height				Days to flower initiation	Flower shedding		Pod initiation
		at 45 DAS	at 90 DAS	at 120 DAS	at Harvest		at 10 DAF	at 20 DAF	
Replication	2	15.38	8.42	105.83**	3.62	2.81	2220.58**	11397.2**	2.11
Treatment	8	37.68	64.66	133.23**	39.18*	24.84**	5646.36**	28875.5**	14.08**
Error	16	14.52	63.68	22.25	13	1.11	328.86	641.491	1.86

Where- DAS- Days after sowing, DAF- Days after flowering,

Table 4.2 Mean sum of squares for morpho–physiological and yield traits.

Source of variation	DF	RLWC	DTE(%)	DSI (%)	RWL mg/min	Pod/plant	Percent pod set	Seed Yield (gm/plant)	Dry matter (gm/plant)	Harvest index (%)
Replication	2	50.36	133**	0.11	0.18	2809.09**	292.51**	3.9	3262.04**	2.08
Treatment	8	124.403**	275**	0.25**	0.72**	1620.13**	88.43**	58.75**	1369.688**	7.1**
Error	16	8.71	33.2	0.32	0.22	196.14	11.23	3.91	1754.75	1.69

Table 4.3 Mean performance for various traits as influenced by different seed hardening chemicals and plant growth regulators.

Treatments	Plant height				Days to Flower Initiation	Flower shedding / plant				Days to Pod Initiation
	at 45 DAS	at 90 DAS	at 120 DAS	at Harvest		at 10 DAF	% Reduction in flower drop	at 20 DAF	% Reduction in flower drop	
T1- $CaCl_2$ (2%)	45.20	89.67	138.37	156.37	118.00	210.12	34.80	418.46	37.72	135.00
T2 - $CaCl_2$ (4%)	47.03	91.33	142.33	159.33	120.67	184.37	42.79	353.04	47.46	135.67
T3- KCl (100 ppm)	46.03	93.17	132.80	157.20	123.00	223.81	30.55	447.15	33.45	137.67
T4- KCl (200 ppm)	45.80	95.47	134.67	159.87	124.00	182.73	43.30	366.40	45.47	138.33
Mean	**46.02**	**92.41**	**137.04**	**158.19**	**121.42**	**200.26**	**37.86**	**396.26**	**41.03**	**136.67**
CD	**10.59**	**6.76**	**11.57**	**11.08**	**2.23**	**43.85**		**55.93**		**2.49**
T5- NAA (20 ppm)	43.53	97.50	145.90	163.23	125.00	266.74	17.23	499.41	25.68	136.33
T6- NAA (40 ppm)	42.04	99.17	147.47	164.80	126.00	251.41	21.99	446.42	33.56	136.67
T7- Triacontanol (20 ppm)	44.07	96.27	144.07	161.40	127.00	245.10	23.95	403.10	40.01	138.33
T8- Triacontanol (40 ppm)	45.13	97.80	145.03	162.30	126.00	241.33	25.12	370.67	44.84	139.00
Mean	**43.69**	**97.68**	**145.62**	**162.93**	**126.00**	**251.15**	**22.07**	**429.90**	**36.02**	**137.58**
CD	**3.44**	**4.98**	**2.08**	**2.1**	**1.52**	**28.73**		**46.82**		**2.13**
T_9- Control	35.19	84.77	128.40	153.47	124.67	322.28	-	671.94	-	132.00
Grand Mean	**43.78**	**93.90**	**139.89**	**159.77**	**123.81**	**236.43**	**-**	**441.84**	**-**	**136.56**
SEm	2.20	4.60	2.72	2.08	0.60	10.47		14.62		0.78
CD at 5 %	6.59	13.81	8.16	6.24	1.82	31.39	-	43.84	-	2.36
CV %	8.70	8.50	3.40	2.30	0.80	7.70	-	5.70	-	1.00

Where- DAS- Days after sowing, DAF- Days after flowering

4.2.4 Days to pod initiation

Significant differences were observed with respect to days to pod initiation due to application of plant growth regulators and seed hardening chemicals (Table 4.3). Days to pod initiation in response to various treatments ranged from 132.0 to 139.0 days. Among seed hardening chemicals, the treatment $CaCl_2$ 2 %recorded lesser number of days (135) to pod initiation, followed by $CaCl_2$4 % (135.67 days)and KCL 100 ppm (137.67 days) whereas among plant growth regulators, NAA 20 ppm(136.33 days) recorded lesser number of days to pod initiation. However, more number of days to pod initiation was recorded in triacontanol 40 ppm (139 days) which was at par with triacontanol 20 ppm (138.33 days), NAA 40 ppm (136.67 days) and KCl 100 ppm (137.67 days) (Table 4.3 and Fig. 4.2).

4.3 Physiological Parameters

4.3.1 Relative leaf water content (%)

Relative leaf water content (RLWC) is another important trait which indicates the drought tolerance ability of different genotypes / treatments by measuring the amount of water to be held by leaves. The data on RLWC as influenced by plant growth regulators and seed hardening chemicals showed

Table 4.4 Mean performance for various traits as influenced by different seed hardening chemicals and plant growth regulators.

Treatments	RLWC	DTE (%)	DSI (%)	RWL mg/min
T1- $CaCl_2$ (2%)	55.07	80.86	0.77	0.21
T2 - $CaCl_2$ (4%)	57.01	75.07	0.71	0.20
T3- KCl (100 ppm)	52.12	90.17	0.86	0.22
T4- KCl (200 ppm)	54.08	83.87	0.80	0.21
Mean	**54.57**	**82.49**	**0.78**	**0.21**
CD	**6.56**	**15.20**	**0.14**	**0.733**
T5- NAA (20 ppm)	62.17	82.47	0.78	0.25
T6- NAA (40 ppm)	64.02	78.45	0.74	0.25
T7- Triacontanol (20 ppm)	59.49	72.26	0.69	0.31
T8- Triacontanol (40 ppm)	61.47	68.37	0.65	0.23
Mean	**61.79**	**75.39**	**0.72**	**0.26**
CD	**5.94**	**9.14**	**0.094**	**0.57**
T_9- Control	43.01	100.00	1.00	0.34
Grand Mean	**56.49**	**81.28**	**0.77**	**0.25**
SEm	1.70	3.32	0.032	0.027
CD at 5 %	5.11	9.98	0.098	0.082
CV %	5.20	7.10	7.40	19.20

Where- DTE- Drought tolerance efficiency, DSI- Drought susceptibility index, RWL- Rate of water loss, RLWC- Relative leaf water content.

significant difference among the treatments (Table 4.4). The average RLWC by plant growth regulators (61.79%) treatments was more than seed hardening treatments (54.57%) (Table 4.4).The relative leaf water content in different treatments ranged from 43.01 to 64.02 %. The treatment with NAA 40 ppm (64.02%) registered higher relative leaf water content followed by NAA 20 ppm (62.17%) and triacontanol 40 ppm (61.47%), These treatments were at par with each other. Among the seed hardening chemicals, $CaCl_2$4 % (57.01%) recorded higher RLWC followed by $CaCl_2$ 2 % (55.07%) and KCl 200 ppm (54.08%), whereas the lowest RLWC (43.01 %) was recorded in control (Table 4.4).

4.3.2 Drought tolerante efficiency (%)

Drought tolerance efficiency (DTE) is an important character to evaluate ability of different genotypes or in response to application of different treatments to perform better under stress condition. Drought tolerance efficiency in response to different seed hardening chemicals and plant growth regulators showed significant differences between treatments (4.2 Table). The average DTE of seed hardening treatments (82.49%) was higher than the average DTE of plant growth regulators (75.39%). Drought tolerance ability of cultivar JKM 189 in response to various seed hardening chemicals and plant growth regulators ranged from 68.37 to 100 %. Among the seed hardening treatments, highest DTE was recorded in KCl 100 ppm (90.17 %) followed by KCl 200 ppm (83.87 %) and NAA 20 ppm (82.47 %) while among plant growth regulators, the highest DTE was recorded in NAA 20 ppm (82.47%) which was at par with NAA 40 ppm (78.45%) (Table 4.4 and fig 4.5).

4.3.3 Drought susceptibility index (%)

The data on drought susceptibility index (DSI) showed significant differences among the treatments indicating that, there was significant influence of different seed hardening chemicals on induction of drought tolerance (Table 4.2). The drought susceptibility index ranged from 0.65 to 1.00. The treatment with triacontanol 40 ppm (0.65%) registered lesser susceptibility index followed by triacontanol 20 ppm (0.69%) and $CaCl_2$ 4% (0.71%). Among the seed hardening chemicals, $CaCl_2$ 4 % (0.71%) recorded lesser DSI followed by $CaCl_2$ 2 % (0.77%)and KCl 200 ppm while among the plant growth regulators, the treatment with triacontanol 40 ppm (0.65%) followed by triacontanol 20 ppm (0.69%) and NAA 40 ppm (0.74%). However, the highest DSI was recorded in control (1.00%) (Table 4.4).

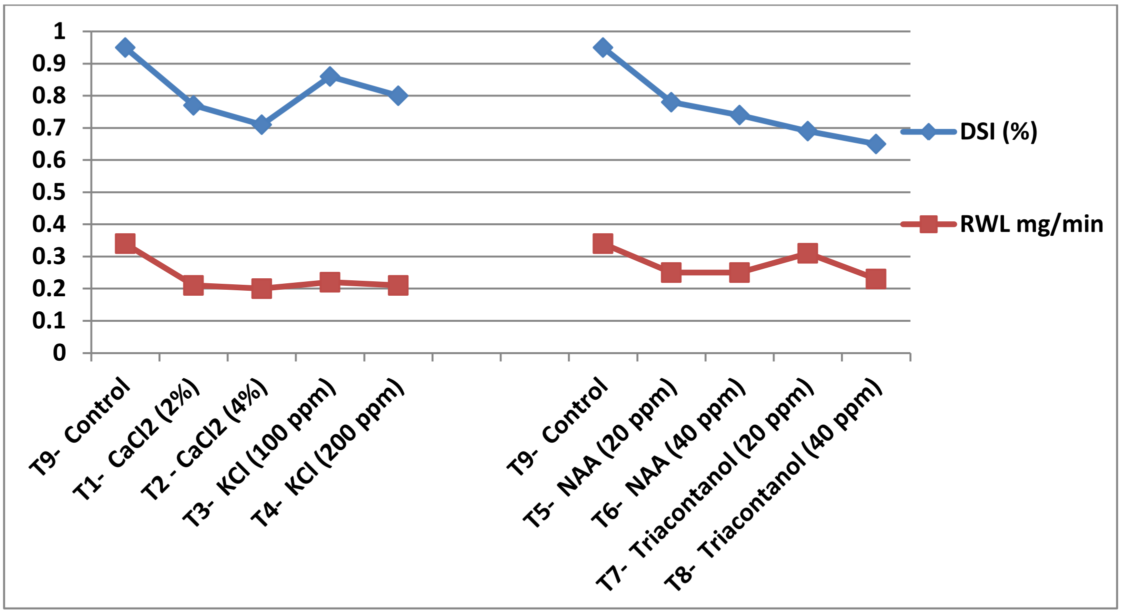

Figure 4.3 Graph showing effect of different seed hardening chemicals and plant growth regulators on drought susceptibility index (%) and relative water loss (mg/min) in pigeonpea.

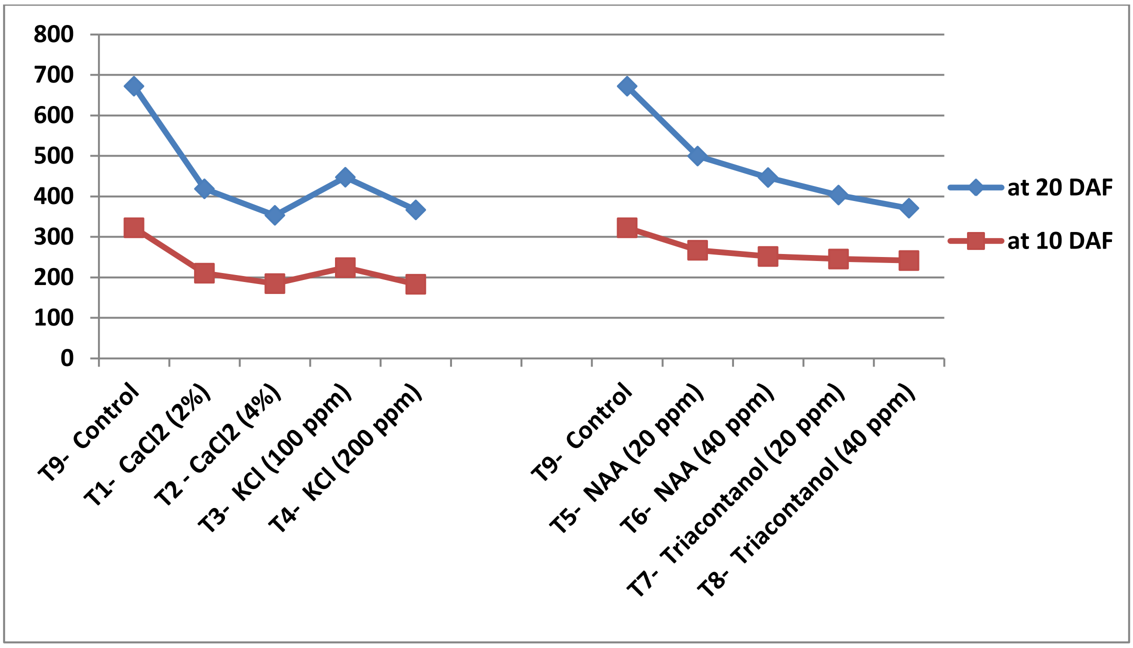

Figure 4.4 Graph showing effect of different seed hardening chemicals and Plant growth regulators on flower shedding at 10 and 20 days after flowering in pigeonpea.

4.3.4 Rate of water loss (RWL)

The result on rate of water loss revealed that there was significant difference between treatments indicating that the rate of water loss from plants significantly affected by use of different seed hardening chemicals and plant growth regulators. The seed hardening chemicals recorded superior in reducing rate of water loss compared to plant growth regulators (Table 4.4). Among seed hardening chemicals, the treatment with $CaCl_2$ 4% (0.20 mg/minute) recorded minimum rate of water loss followed by $CaCl_2$ 2 % (0.21 mg/minute) and KCl 200 ppm (0.21 mg/minute) while it was recorded as maximum in control (0.34 mg/minute) (Table 4.4). The application of plant growth regulators had also reduced rate of water loss, Among those triacontanol 40 ppm (0.23 mg/minute) recorded superior in reducing RWL followed by NAA 20 ppm (0.25 mg/minute) and NAA 40 ppm (0.25 mg/minute) (Fig. 4.3).

4.4 Yield and yield components

4.4.1 Number of pods per plant

Number of pods per plant showed significant differences among the treatments (Table 4.5).The number of pods in response to various seed hardening chemicals and plant growth regulators ranged from 185.0 to 268.63 pods/plant. The maximum number of pods per plant were noticed in treatment triacontanol 40 ppm (268.63 pods/plant) which was at par with triacontanol 20 ppm (257.40 pods/plant) and NAA 40 ppm (248.53 pods/plant). It was further noticed that in different concentrations of seed hardening chemicals, the treatment with KCl 200 ppm (248.33 pods/plant) recorded maximum number of pods per plant followed by $CaCl_2$4 % (241.47 pods/plant) and $CaCl_2$2 % (240.40 pods/plant). All the treatments of seed hardening chemicals were at par with each other for number of pods per plants. In general, all the treatments had more number of pods per plant over control (185 pods/plant) indicating that there was significant effect of application of different seed hardening chemicals and plant growth regulators on number of pods/plant.

Table 4.5 Mean performance for various traits as influenced by different seed hardening chemicals and plant growth regulators.

Treatments	Pod /plant	Percent pod set	% Increase in pod Set	Seed yield (gm/plant)	Dry matter (gm/plant)	Harvest index (%)
T1- $CaCl_2$ (2%)	240.40	35.04	57.49	38.97	260.00	15.04
T2 - $CaCl_2$ (4%)	241.47	38.84	74.57	42.27	265.00	15.97
T3- KCl (100 ppm)	239.93	32.23	44.89	37.33	256.67	15.12
T4- KCl (200 ppm)	248.33	37.79	69.87	39.27	263.33	15.89
Mean	**242.53**	**35.97**	**61.71**	**39.46**	**261.25**	**15.50**
CD	**20.93**	**5.88**		**3.83**	**36.42**	**1.99**
T5- NAA (20 ppm)	247.93	31.69	42.43	38.29	288.33	14.67
T6- NAA (40 ppm)	248.53	34.26	54.00	40.17	290.00	15.24
T7- Triacontanol (20 ppm)	257.40	37.92	70.45	43.97	293.33	16.40
T8- Triacontanol (40 ppm)	268.63	40.06	80.09	45.31	296.67	16.51
Mean	**255.63**	**35.98**	**61.74**	**41.94**	**292.08**	**15.70**
CD	**30.78**	**7.70**		**4.12**	**122.15**	**2.84**
T_9- Control	185.00	22.25		30.10	233.33	11.40
Grand Mean	**241.96**	**34.45**		**39.52**	**271.85**	**15.14**
SEm	8.08	1.93		1.14	24.1	0.75
CD at 5 %	24.24	5.80		3.42	72.51	2.25
CV %	5.80	9.70		5.00	15.40	8.60

4.4.2 Pod set percent

The data on pod set per cent presented in Table 4.5 indicated a significant increase in pod setting percent due to application of various Plant growth regulators and seed hardening chemicals over control.The data revealed that there was significant difference among treatments for pod setting percent (4.5 Table). The pod setting percent ranged from 22.25 to 40.06 %. The average pod setting percent of different treatments of seed hardening chemicals (35.97%) and plant growth regulators (35.98%) was approximately similar (Table 4.5). The treatment with triacontanol 40 ppm recorded higher pod set per cent (40.06 %) which was at par with $CaCl_2$ 4% (38.84 %) and triacontanol 20 ppm (37.92 %). Among the seed hardening treatments, $CaCl_2$ 4% registered higher pod set per cent (38.84 %) at par with KCl 200 ppm (37.79%) and $CaCl_2$ 2% (34.04%).The lesser pod set per cent was recorded in control (22.25%).

The percent increase in pod set showed that among the plant growth regulators, the maximum (80.09 %) increment was observed in triacontanol 40 ppm followed by triacontanol 20 ppm (70.45%) and NAA 40 ppm (54.00%) while among the seed hardening chemicals, the highest percent increment (74.57 %) in pod set was recorded in $CaCl_2$ 4 % followed by KCl 200 ppm (69.87%) and $CaCl_2$ 2 % (57.49%).

4.4.3 Seed yield (g plant^{-1})

The data on seed yield (g) per plant presented in Table 4.5 indicated a significant increase in seed yield per plant over control due to application of various seed hardening chemicals and plant growth regulators. The seed yield per plant ranged from 30.10 to 45.31 gram per plant. Among the plant growth regulators, the maximum seed yield per plant (45.31 gm) was obtained with treatment triacontanol 40 ppm which was significantly higher over NAA 40 ppm (40.17 gm/plant) and NAA 20 ppm (38.29 gm/plant), and at par with triacontanol 20 ppm (43.97 gm/plant). Among the seed hardening chemicals $CaCl_2$ 4% registered maximum seed yield of 42.27 gram per plant which was at par with KCL 200 ppm (39.27 gm/plant) and significantly superior to $CaCl_2$ 2% (38.97 gm/plant) and KCl 100 ppm (37.33 gm/plant) (Fig. 4.6).

4.4.4 Total dry matter production (g plant^{-1})

The data on total dry weight revealed significant differences due to the application of plant growth regulators and agrochemicals (Table 4.2). The total dry matter production per plant in different treatments ranged from 233.33 to 296.67 gm. The average dry matter produce by different treatments of plant growth regulators (292.08 gm) was greater as compared to seed hardening chemicals (261.25 gm). The overall highest total dry weight was recorded in triacontanol 40 ppm (296.67 gm) followed by triacontanol 20 ppm (293.33gm) while the minimum dry weight was recorded in control (233.33 gm) (Table 4.5). Among the seed hardening chemicals, the treatment $CaCl_2$ 4% (265 gm) registered higher values of total dry matter over all other treatments which was at par with all other seed hardening treatments. Among plant growth regulators, the treatments triacontanol 40 ppm (296.67 gm) recorded higher value followed by triacontanol 20 ppm (293.33 gm) and NAA 40 ppm (290 gm) which at par with each other.

4.**4.5 Harvest index (%)**

The data pertaining to the harvest index as influenced by plant growth regulators and seed hardening chemicals showed significant differences among the treatments (Table 4.2). The harvest index ranged from 11.40 to 16.51 %. Among plant growth regulators, the treatment with triacontanol 40 ppm registered higher harvest index of 16.51% which was at par with triacontanol 20 ppm (14.40%) and NAA 40ppm (15.24%). Among the seed hardening chemicals, $CaCl_2$ (4 %) recorded higher harvest index of 15.97% followed by KCl 200 ppm (15.89%) and KCl 100 ppm (15.12%), all the treatments of seed hardening chemicals were at par with each other.

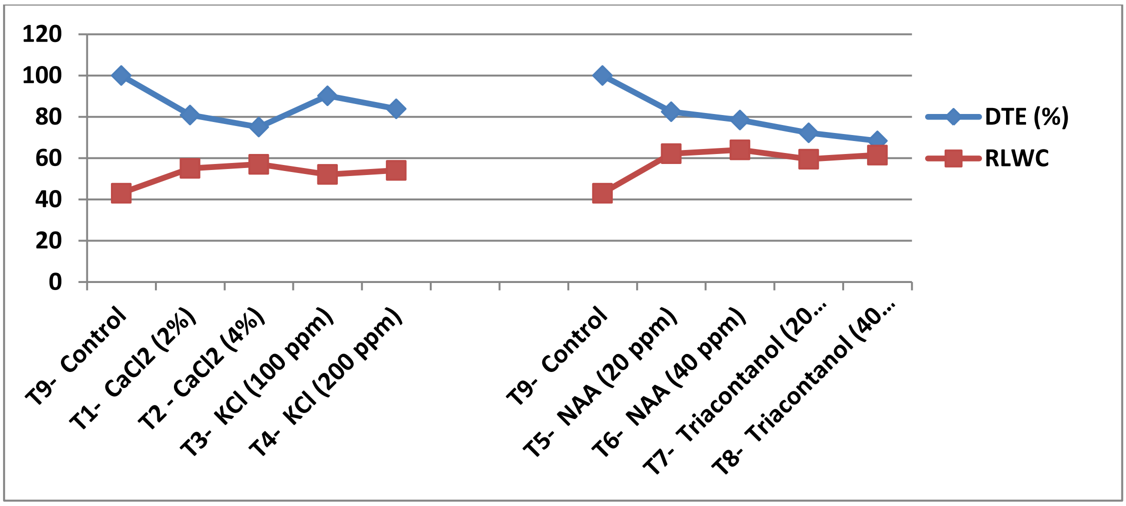

Figure 4.5 Graph showing effect of different seed hardening chemicals and Plant growth regulators on drought tolerance efficiency (%) and relative leaf water content (%).

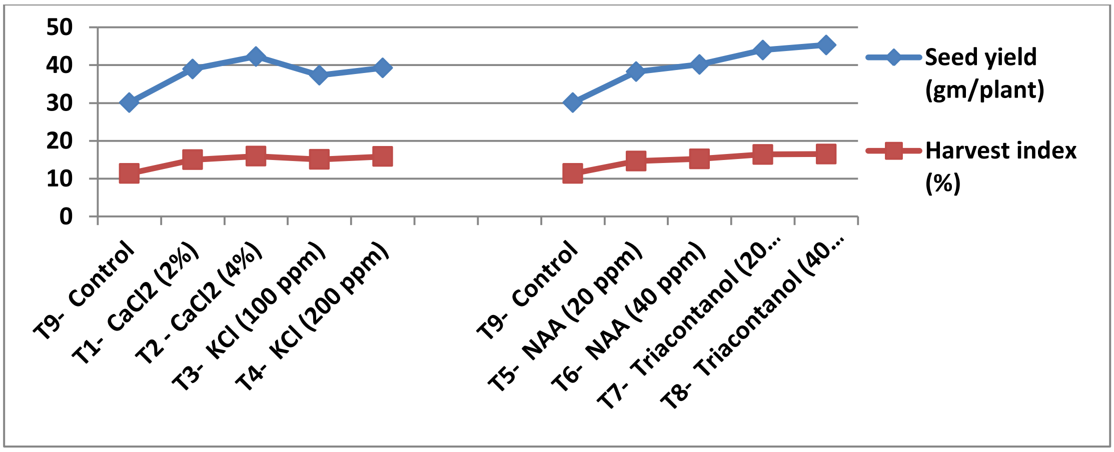

Figure 4.6 Graph showing effect of different seed hardening chemicals and Plant growth regulators on seed yield per plant and harvest index (%).

CHAPTER V
DISCUSSION

Pulses are the basic ingredient in the diets of a vast majority of Indian population as they provide a perfect mix of high biological value when supplemented with cereals. The progressive decline in per capita availability of pulses in India is a matter of great concern. There is a need to improve productivity potential of pulses in dry regions. Among the pulses, pigeonpea plays an important role and it is generally grown under drought situations. Hence, there is a need to improve the productivity potential under drought conditions, by various techniques like seed hardening and use of plant growth regulators (PGR's).

The productivity potential of pigeonpea is much lower as compared to other countries. The main challenges in the future scenario will revolve around attaining self sufficiency in pigeonpea production, to meet the increased demand of protein and ensuring the environmental security. Pigeonpea is mainly grown under different agro-ecological constraints as more than 95 per cent area is under rainfed condition. It is normally cultivated as a rainfed crop and is often subjected to water stress at one or several stages of crop growth and development, as it is a long duration crop. It has been envisaged that better technology, particularly use of plant growth regulators and seed hardening techniques are known to enhance the source - sink relationship and stimulate the better translocation of photo-assimilates towards the developing pods (Dhanoji,2011).

Plant growth regulators may be considered as a new generation agrochemicals after fertilizers, pesticides and herbicides. These are the chemical substances, when added in small amounts, modify the growth of plants, usually by stimulating or inhibiting part of the natural growth regulatory system. The naturally occurring growth regulators (hormones) normally control plant growth and modification of growth can be achieved by the exogenous application growth regulators. Plant growth regulators, when applied externally, and phytohormones, when produced internally, are substances that influence physiological processes of plants at very low concentrations. Both these terms have been used interchangeably, particularly when referring to auxins, gibberellins, cytokinins, ethylene and abscisic acid (Taiz and Zeiger, 2006). Under drought, endogenous contents of auxins, gibberellins and cytokinin usually decrease, while those of abscisic acid and ethylene increase (Nilsen and Orcutte, 1996). Nevertheless, phytohormones play vital roles in drought tolerance of plants. Auxins induce new root formation by breaking root apical dominance induced by cytokinins. As a prolific root system is vital for drought tolerance, auxins have an indirect but key role in this regard. Drought stress limits the production of endogenous auxins, usually when contents of abscisic acid and ethylene increase (Nilsen and Orcutte, 1996). The growth regulators include both growth promoters and retardants, which have been shown to modify the canopy structure and other yield attributes. The PGR's are also known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates, thereby increasing the productivity of crop.

To combat adverse moisture scarcity conditions, matching agro-techniques need to be evolved for various agro-ecological regions. Pre-sowing seed treatment to induce hardening (Misra and Dwivedi, 1980; Henckel, 1964 and Singh and Chatterjee, 1980), foliar spray of fertilizer solution during ontogenesis (Frewal and Mittal, 1982 and Dev and Dev, 1980) and mulching (Ali and Prasad, 1974 and Umrani *et al*., 1973) have been reported to increase productivity of pulses in rainfed areas. Most of the research work done so far has been on understanding the mechanisms underlying productivity, but very little has been done with respect to the possibilities of overcoming stress or limitations imposed by environmental factors. It is important at this juncture to see and understand how best the stress effect can be minimized by adopting different strategies and to elucidate the impact of such strategies in enhancing productivity potential under water limited conditions. Few workers have studied the use of seed hardening techniques and foliar sprays of PGRs in different crops. However, the study in this direction on pigeonpea is very meagre.

With this background, present investigations were carried out to understand the effect of plant growth regulators and seed hardening chemicals for drought tolerance in pigeonpea, the results obtained are discussed in this chapter.

5.1 Morphological Characters

The plant growth regulators and seed hardening chemicals significantly influenced different morphological characters *viz*., plant height, days to flower initiation and days to pod initiation.

5.1.1 Plant height (cm)

Basically, plant height is a genetically controlled character, but several studies have indicated that the plant height can be increased or decreased by the application of synthetic plant growth regulators. However, in the present investigation, significant differences in plant height were noticed due to plant growth regulators and seed hardening chemicals at stage of 120 DAS and at harvest while there was non-significant difference among the treatments for plant height at 45 and 90 DAS. The average plant height of treatments of plant growth regulators was greater than seed hardening chemicals. Among plant growth regulators, the treatment with NAA 40 ppm registered significantly higher plant height which was at par with NAA 20 ppm, triacontanol 20 & 40 ppm and $CaCl_2$ 4 % at 120 DAS and at harvest. Jayaram Reddy (2001) also reported significant increment in plant height at various stage of plant growth. Ali Khan and Apparao (1969) reported that foliar spray of NAA significantly increased the plant height and stem length and reduced the leaf senescence. Similar results have also been reported by Arora *et al.*, (1990) in okra.

5.1.2 Days to flower initiation

Flower initiation is an important phenological stage which determines the plant productivity. In general, seed hardening chemicals took lesser days to flower initiation compared to plant growth regulators. Among seed hardening chemicals, the treatment with $CaCl_2$ 2 % was superior with lesser number of days to flower initiation followed by $CaCl_2$ 4 % and KCl 100 ppm. Among the plant growth regulators, the treatment NAA 20 ppm recorded lesser number of days to flower initiation followed by NAA 40 ppm while the maximum number of days for flower initiation taken in triacontanol 20 ppm which was even greater than control indicating that the application of plant growth regulators extended the number of days to flower initiation. The earliness in flower initiation was reported due to use of seed hardening chemicals and similar reports were also made by Rabi *et al.,* (1991) in *Vicia faba* and Bhattacharya and Sharma (2001) in pigeonpea.

5.1.3 Flower shedding

There was significant difference between treatments for number of flower dropped at 10 and 20 days after flowering indicating significant influence of plant growth regulators and seed hardening chemicals on reducing rate of flower shedding. At 10 days after flowering, the average flower shedding in seed hardening treatments was lesser than plant growth regulators. The minimum flower shedding was recorded in KCl 200 ppm which was at par with $CaCl_2$ 4% and $CaCl_2$ 2 % while the maximum flower shedding was noticed in control. Among plant growth regulators, the minimum flower shedding noticed in triacontanol 40 ppm followed by triacontanol 20 ppm and NAA 40 ppm. The highest (43.3 %) reduction in flower drop was recorded in KCl 200 ppm followed by $CaCl_2$ 4 % (42.79 %) and $CaCl_2$ 2 % (34.08%).

At 20 days after flowering, the minimum flower shedding was recorded in $CaCl_2$ 4 % which was at par with KCl 200 ppm while among the plant growth regulators, the minimum flower shedding was noticed in triacontanol 40 ppm which was at par with triacontanol 20 ppm whereas the maximum number of flower dropped in control at both the stages. The highest percent reduction in flower drop (47.46 %) was recorded in $CaCl_2$ 4 % followed by $CaCl_2$ 2 % (37.72 %) and KCl 200 ppm (45.47%). The enhanced number of pods per plant and reduced flower drop in pigeonpea was noticed by Prakasa Rao and Narayanan (1997).

5.1.4 Days to pod initiation

Significant differences were observed with respect to days to pod initiation due to the application of plant growth regulators and seed hardening chemicals Among seed hardening chemicals, the treatment $CaCl_2$ 2 % recorded lesser number of days taken for pod initiation, followed by $CaCl_2$ 4 % and KCL 100 ppm as compared to control, whereas among plant growth regulators, NAA 20 ppm had recorded lesser number of days to pod initiation. More number of days to pod initiation was recorded in triacontanol 40 ppm followed by triacontanol 20 ppm, NAA 40 ppm and KCl 100 ppm. It is inferred that the phenological stages *viz.,* days to flower initiation and days to pod initiation are early due to application of seed hardening chemicals and plant growth regulators. Similar reports have also been made by Varma *et al.,* (2004) in pigeonpea and Garai and Datta (2003) in greengram.

5.2 Physiological Parameters

5.2.1 Relative leaf water content (%)

A better understanding of different biophysical characters and their relationship with yield and other physiological process is essential. In this direction, influence of plant growth regulators and agrochemicals on relative leaf water content was studied. Relative leaf water content (RLWC) is an important trait which indicates the drought tolerance ability of different genotypes by measuring the amount of water present in the leaf tissue in relation to turgid condition and the treatments having higher RLWC under drought condition would be preferable to maintain higher water balance. The average relative leaf water content by plant growth regulators treatments was more than seed hardening treatments. The treatment with NAA 40 ppm registered higher relative leaf water content followed by NAA 20 ppm and triacontanol 40 ppm. These results are in concurrence with Patil (1987) in sorghum and Amaregouda *et al.,* (1994) in wheat. Among the seed hardening chemicals, $CaCl_2$ 4 % recorded higher RLWC followed by $CaCl_2$ 2 % and KCl 200 ppm. The higher value of relative leaf water content helps to maintain favourable water balance particularly under rainfed/limited water supply conditions. The increase in RLWC due to the application of plant growth regulators could be due to their ability in hormone directed translocation of photosynthates leading to better osmoregulation and enhanced RLWC.

5.2.2 Drought tolerance efficiency (%)

Drought tolerance is defined as the ability to grow, flower and display economic yield under suboptimal water supply. However, drought tolerance efficiency (DTE) is the ability of different genotypes or in response to application of different treatments to perform better under moisture stress condition. Drought tolerance efficiency in response to different seed hardening chemicals and plant growth regulators showed significant differences between treatments. The average DTE of seed hardening treatments was higher than the average DTE of treatments of plant growth regulators. Among the seed hardening treatments, highest DTE as compared to control was recorded in KCl 100 ppm followed by KCl 200 ppm and NAA 20 ppm indicating their influence on induction drought tolerance efficiency. Among plant growth regulators, the highest DTE was recorded in NAA 20 ppm followed by NAA 40 ppm while the control had lowest DTE indicating that the application of different seed hardening chemicals and PGRs significantly increased drought tolerance efficiency in pigeonpea. Similarly, Selvi *et al.* (2009) reported significantly higher yield and drought tolerance ability due to application of 2 % solution of $CaCl_2$ or KH_2PO_4, foliar spray of 2 % urea and 2 % KCl in pigeonpea.

5.2.3 Drought susceptibility index (%)

The significant difference among the treatments for drought susceptibility index (DSI) indicating that there was significant influence of different seed hardening chemicals on induction of drought tolerance. The treatment with triacontanol 40 ppm registered lesser susceptibility index followed by triacontanol 20 ppm and $CaCl_2$ 4%. Among the seed hardening chemicals, $CaCl_2$ 4 % recorded lesser DSI followed by $CaCl_2$ 2 % and KCl 200 ppm while among the plant growth regulators, the treatment with triacontanol 40 ppm followed by triacontanol 20 ppm and NAA 40 ppm. The highest DSI was recorded in control. Pothalkar and Nawalagatt (2007) also reported significant influence of different treatment of plant growth regulators and seed hardening chemicals to induce drought tolerance efficiency and reduce drought susceptibility in pigeonpea

5.2.4 Rate of water loss (RWL)

The result on rate of water loss revealed that there was significant difference between treatments. The seed hardening chemicals were found superior in reducing rate of water loss compared to plant growth regulators. Among seed hardening chemicals, the treatment with $CaCl_2$ 4% (0.20 mg / minute) was recorded minimum rate of water loss followed by $CaCl_2$ 2% (0.21

mg/ minute) and KCl 200 ppm. The application of plant growth regulators had also reduced rate of water loss, among those triacontanol 40 ppm (0.23 mg / minute) had been observed superior in reducing RWL followed by NAA 20 ppm and NAA 40 ppm while it was recorded as maximum in control indicating that the rate of water loss from plants was significantly affected by use of different seed hardening chemicals and plant growth regulators. (Henry and Gorden,1980)

5.3 Yield and yield components

5.3.1 Number of pods per plant

The number of pods in response to various seed hardening chemicals and plant growth regulators was increased. The maximum number of pods per plant noticed with treatment triacontanol 40 ppm followed by triacontanol 20 ppm and NAA 40 ppm. It was further noticed that in different concentrations of seed hardening chemicals has also significantly increased the number of pods/ plant. The treatment with KCl 200 ppm recorded maximum number of pods per plant followed by $CaCl_2$ 4 % and $CaCl_2$ 2 %. In general, all the treatments of seed hardening chemicals and PGRs had more number of pods per plant over control indicating that there was significant effect of application of different seed hardening chemicals and plant growth regulators on number of pods/plant. Similarly, Tripathi *et al.* (2009) reported increased flowering and higher number of pods plant^{-1} due to foliar spray of TIBA (2, 3, 5-triiodobenzoic acid, 25 mg and 50 mg l^{-1}) and NAA (25 mg and 50 mg l^{-1})

5.3.2 Pod set percent

The results of pod set per cent revealed a significant increase in pod setting percent due to application of various plant growth regulators and seed hardening chemicals over control. The pod setting percent ranged from 22.25 to 40.06 %. The average of pod setting percent of different treatments of seed hardening chemicals (35.97 %) and plant growth regulators (35.98 %) was approximately similar indicating their equal effect on per cent pod set. The treatment with triacontanol 40 ppm recorded higher pod set per cent (40.06 %) followed by $CaCl_2$ 4 % (38.84 %) and triacontanol 20 ppm (37.92 %). Among the seed hardening treatments, $CaCl_2$ 4 % registered higher pod set per cent (38.84

%) followed by KCl 200 ppm (37.79 %) and $CaCl_2$ 2 % (34.04 %).The lesser pod set per cent was recorded in control (22.25 %). The foliar application of miraculan at 60 days after sowing increased grain yield per plant significantly with 0.5 and 1.0 per cent treatment and was due to combined effect of increase in grain size and pod number in pigeonpea (Bangal *et al.,* 1984).

The percent increment in pod set as compared to control showed that, the maximum (80.09 %) increment was achieved with the application of triacontanol 40 ppm followed by triacontanol 20 ppm (70.45 %) and NAA 40 ppm (54.00 %) while among the seed hardening chemicals, the highest (74.57 %) percent increment in pod set was recorded in $CaCl_2$ 4 % followed by KCl 200 ppm (69.87 %) and $CaCl_2$ 2 % (57.49 %). Tripathi *et al.* (2009) also reported increment in pod setting as compared to control due to application of PGRs in pigeonpea.

5.3.3 Seed yield (g plant^{-1})

The influence of plant growth regulators and seed hardening chemicals significantly increased the seed yield. The increased seed yield could be attributed to higher dry matter production and its accumulation in reproductive parts, lesser flower drop and higher pod setting. The data on seed yield per plant indicating a significant increase in seed yield per plant over control due to application of various seed hardening chemicals and plant growth regulators. Among the plant growth regulators, the maximum seed yield per plant was obtained with treatment triacontanol 40 ppm which was significantly higher over NAA 40 ppm and NAA 20 ppm and at par with triacontanol 20 ppm. Similarly, Pujari *et al.* (1998) reported significant improvement in seed yield of pigeonpea due to foliar application of urea and triacontanol. Among the seed hardening chemicals $CaCl_2$ 4 % registered maximum seed yield followed by KCL 200 ppm and significantly superior to $CaCl_2$ 2 % and KCl 100 ppm. Reddy et al. (2009) also reported significantly higher yield due to application of seed hardening chemicals KH_2PO4 or $CaCl_2$. The increase in seed yield with respect to seed hardening treatments was probably due to maximum water absorbing capacity of seeds, more intense photosynthetic activity and more tissue hydration, thereby enabling the plant to resist soil moisture stress more efficiently (Henckel, 1964). This is in confirmity with the findings of earlier research workers that pre-sowing seed hardening with cycocel (50 mg/1) recorded significantly higher yield per plant in okra (Mehrotra *et al.,* 1970). Seed hardening with $CaCl_2$ (1%) also recorded significantly higher number of pods per plant and pod yield in groundnut (Arjunan and Srinivasan, 1989).

The highest (50.53 %) percent increment in seed yield per plant as compared to control was recorded in triacontanol 40 ppm followed by triacontanol 20 ppm indicating that application of PGRs had increased more seed yield per plant compared to seed hardening chemicals. Similarly, Shindhe and Jadhav (1995) observed the effect of NAA (40 ppm) and reported increased yield in pigeonpea. Amaregouda *et al.,* (1994) noticed that treatment with $CaCl_2$ (2 %) gave higher yield in wheat. Puste and Kundu (1995) observed that foliar spray of triacontanol (5 ml/1) increases tuber yield in potato. Chougale (1997) showed that, miraculan and cytozyme are known to affect various physiological traits and increased yield potential of sesamum. Triacontanol (miraculan) is a naturally occurring long chain carbon compound, which has been reported to stimulate plant growth by enhancing photosynthesis and nutrient uptake (Ries *et al.,* 1976).

5.3.4 Total dry matter production (g plant^{-1})

Dry matter production is of greater significance in the determination of yield. With the application of plant growth regulators and seed hardening chemicals, the canopy structure and distribution in leaves can be improved. In the present investigation, the application of PGR's enhanced more accumulation of dry matter compared to seed hardening chemicals because the application of PGRs in associated with higher photosynthesis and greater biomass production. The overall highest total dry weight was recorded in triacontanol 40 ppm followed by triacontanol 20 ppm while the minimum dry weight was recorded in control. The plant growth regulators were more effective in increasing the total dry matter as compared to seed hardening treatments. The association of total dry matter with grain yield indicating the importance of this parameter in boosting the source-sink relationship and yield potential. Similar observations were made by Nam *et al.,* (1998) and Katti *et al.,* (1999) in pigeonpea. Among the seed hardening chemicals, the treatment $CaCl_2$ 4 % registered higher values of total dry matter production over all other treatments which was at par with all other seed hardening treatments. The foliar application of NAA at flowering lead to higher total dry matter production and leaf dry weight in soybean and pigeonpea (Merlo *et al.,* 1987 and Shindhe and Jadhav, 1995), potato (Padmavathi, 1995) and blackgram (Prabhu 2000).

5.**3.5 Harvest index (%)**

The data pertaining to the harvest index as influenced by plant growth regulators and seed hardening chemicals showed significant differences among the treatments. Among plant growth regulators, the treatment with triacontanol 40 ppm registered higher harvest index followed by triacontanol 20 ppm and NAA 40 ppm. Tripathi et al. (2009) also reported that the seed yield and harvest index of pigeonpea by 20.9 % and 25.0% over control, respectively due to application of plant growth regulators. Among the seed hardening chemicals, $CaCl_2$ 4 % recorded higher harvest index of followed by KCl 200 ppm and KCl 100 ppm. Masood Ali (1985) also observed that foliar spray of KCl (2 %) solution significantly increases grain yield in chickpea. The more increase in economic yield as compared to biological yield leads to greater harvest index and *vice versa*. The increase in the economic yield of pigeonpea due to foliar spray of triacontanol (0.5 ml/l) has been reported (Patil and Bangal 1985).

CHAPTER VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

A field experiment entitled, "Evaluation of plant growth regulators and seed primers for drought tolerance in pigeonpea (*Cajanus cajan* (L.) Millsp.) was conducted during *kharif* 2013 on Experimental field of AICRP-Pigeonpea at R.A.K. College of Agriculture, Sehore, Madhya Pradesh (23º12'N, 77º05'E & 498.7 MSL). The major aim of this study was to evaluate the influence of plant growth regulators and seed hardening chemicals on various morphological, physiological and yield parameters of pigeonpea genotype JKM 189. The experiment consisted of nine treatments of different concentration of seed hardening chemical and plant growth regulators. The experiment was laid out in randomized complete block design with three replications. Observations were recorded on plant height (cm) days to flower initiation, flower shedding, days to pod initiation, number of pods per plant, per cent pod set, seed yield (g/plant), total dry matter production (gm/plant) and harvest index (%) along with some physiological observations such as relative leaf water content (RLWC), rate of water loss (mg/min), drought susceptibility index (%) and drought tolerant efficiency (%). The results obtained from the present investigation are summarized in this chapter.

6.1 Summary

1. It was observed in general that the performance of different treatments with respect to morpho -physiological, growth parameters and yield and yield components was better as compared to control due to application of different seed hardening chemicals and plant growth regulators.

2. Significant differences were observed between the treatments for all the characters except for plant height at 45 and 90 DAS (days after sowing) indicating that there was significant influence of differente plant growth regulators and seed hardening chemicals on various morphological, physiological and yield parameters in pigeonpea.

3. Plant growth regulators (PGR's) recorded significantly higher values as compared to seed hardening chemicals for plant height at all the stages. Among, all the treatments NAA (20 ppm) and NAA (40 ppm) were found to be more effective in increasing plant height as compared to seed hardening treatments.

4. In general, seed hardening chemicals took lesser days to flower initiation (121.42 days) compared to plant growth regulators (126 days). Among seed hardening chemicals, the treatment with $CaCl_2$ 2 % was superior with lesser number of days to flower initiation (118 days) followed by $CaCl_2$ 4 % (120.67 days) while among the plant growth regulators, the treatment NAA 20 ppm recorded lesser number of days to flower initiation (125 days) followed by NAA 40 ppm (126 days).

5. At 10 days after flowering, the average flower shedding in seed hardening treatments (200.26) was lesser than plant growth regulators (251.15). The minimum flower shedding was recorded in KCl 200 ppm (182.73) while the maximum flower shedding was noticed in control (322.28). The highest percent reduction in flower drop (43.3 %) was recorded in KCl 200 ppm followed by $CaCl_2$ 4 % (42.79 %) and $CaCl_2$ 2 % (34.08 %).

6. The treatment $CaCl_2$ 2 % recorded lesser number of days (135) to pod initiation followed by $CaCl_2$ 4 % (135.67 days) and KCL 100 ppm (137.67 days) whereas among plant growth regulators, NAA 20 ppm (136.33 days) had recorded lesser number of days to pod initiation.

7. The average RLWC was more in plant growth regulators (61.79 %) than seed hardening treatments (54.57 %). The treatment with NAA 40 ppm (64.02 %) registered higher relative leaf water content followed by NAA 20 ppm (62.17 %) and triacontanol 40 ppm (61.47 %). Among the seed hardening chemicals, $CaCl_2$ 4 % (57.01%) recorded higher RLWC followed by $CaCl_2$ 2 % (55.07 %) and KCl 200 ppm (54.08 %).

8. The average drought tolerance efficiency of seed hardening treatments (82.49 %) was higher than the average DTE of plant growth regulators (75.39 %). The highest DTE was recorded in KCl 100 ppm (90.17 %) followed by KCl 200 ppm (83.87 %) and NAA 20 ppm (82.47 %) while among plant growth regulators,

the highest DTE was recorded in NAA 20 ppm (82.47 %) followed by NAA 40 ppm (78.45 %).

9. The treatment with triacontanol 40 ppm (0.65 %) registered lesser susceptibility index followed by triacontanol 20 ppm (0.69 %) and $CaCl_2$ 4 % (0.71 %). However, the highest DSI was recorded in control (1.00 %)

10. The seed hardening chemicals was superior in reducing rate of water loss compared to plant growth regulators. Among seed hardening chemicals, the treatment with $CaCl_2$ 4% (0.20 mg/minute) recorded minimum rate of water loss followed by $CaCl_2$ 2 % (0.21 mg/minute) and KCl 200 ppm (0.21 mg/minute) while it was recorded as maximum in control (0.34 mg/minute). The application of triacontanol 40 ppm (0.23 mg/minute) was recorded superior among all PGRs in reducing RWL followed by NAA 20 ppm (0.25 mg/minute) and NAA 40 ppm (0.25 mg/minute).

11. The maximum number of pods per plant noticed with treatment triacontanol 40 ppm followed by triacontanol 20 ppm and NAA 40 ppm. It was further noticed that in different concentrations of seed hardening chemicals, the treatment with KCl 200 ppm recorded maximum number of pods per plant followed by $CaCl_2$ 4 % and $CaCl_2$ 2 %.

12. The treatment with triacontanol 40 ppm recorded higher pod set per cent (40.06 %) followed by $CaCl_2$ 4 % (38.84 %) and triacontanol 20 ppm (37.92 %). Among the seed hardening treatments, $CaCl_2$ 4 % registered higher pod set per cent (38.84 %) at par with KCl 200 ppm (37.79 %) and $CaCl_2$ 2 % (34.04 %).The lesser pod set per cent was recorded in control (22.25 %).

13. The maximum seed yield per plant (45.31 gm) was obtained with treatment triacontanol 40 ppm followed by NAA 40 ppm (40.17 gm/plant) and NAA 20 ppm (38.29 gm/plant). Among the seed hardening chemicals $CaCl_2$ 4 % (42.27 gm/plant) registered maximum seed yield followed by KCL 200 ppm (39.27 gm/plant) and $CaCl_2$ 2 % (38.97 gm/plant).

14. Dry matter accumulation in leaves differed significantly between the treatments. The overall highest total dry matter was recorded in triacontanol 40 ppm (296.67 gm) followed by triacontanol 20 ppm (293.33 gm). Among the seed

hardening chemicals, the treatment $CaCl_2$ 4 % (265 gm) registered higher values of total dry matter over all other treatments while the minimum dry weight was recorded in control (233.33 gm).

15. The treatment with triacontanol 40 ppm registered higher harvest index of 16.51 % which was a par with triacontanol 20 ppm (14.40%) and NAA 40 ppm (15.24 %). Among the seed hardening chemicals, $CaCl_2$ (4 %) recorded higher harvest index of 15.97 % followed by KCl 200 ppm (15.89 %) and KCl 100 ppm (15.12 %).

6.2 Conclusion

The study on effect of plant growth regulators and seed primers for drought tolerance revealed that various physiological and yield components of pigeonpea viz., plant height, days to flower initiation, days to pod initiation flower shedding, pod setting, number pods per plant, pod set per cent, relative leaf water content, rate of water loss, drought tolerance efficiency and seed yield differed significantly due to the application of plant growth regulators and seed hardening chemicals. The effect of plant growth regulators was more pronounced than seed hardening chemicals for many traits. The present study also revealed that treatment with triacontanol 40 ppm was superior among all other treatments for increase in percent pod set, seed yield, total dry matter production and harvest index. This could probably be due to beneficial effects of plant growth regulator treatments which are involved in enhancement of photosynthesis and nitrogen metabolism which are the major physiological process influencing plant growth and development. Based on the above results it is concluded that among the plant growth regulator, the application of triacontanol 40 ppm followed by triacontanol 20 ppm and NAA (40 ppm) was found more beneficial and significantly improved all the morpho-physiological traits, growth parameters and yield and yield components in pigeonpea. The present study also indicated clearly that growth regulators are very effective in increasing yield and yield attributes compared to seed hardening treatments in pigeonpea.

Seed hardening chemicals were effective to induce drought tolerance efficiency in pigeonpea. The treatment with KCl 100 ppm was superior among all other for significant increase in drought tolerance efficiency. Seed hardening treatments such as $CaCl_2$ 2 % and $CaCl_2$ 4 % recorded superior for early flowering and pod initiation as well as lesser flower drop and higher pod setting percent which leads to higher yield under moisture stress conditions.

6.3 Suggestions for further work

Information on influence of different seed hardening chemicals and plant growth regulators on various traits of pigeonpea is very important and helpful in planning of future breeding programmes to develop high yielding varieties for cultivation in those areas having less irrigation facilities or rainfed cropping pattern. On the basis of present investigation, breeding repercussions and suggestions have been made for further works are given below:

1. There are number of commercial formulations of plant growth regulators which need to be tested at different concentrations. Similarly, several chemicals having the potential of seed hardening can be tested in pigeonpea.

2. The knowledge is less about influence of different plant growth regulators and seed hardening chemicals on enzyme activity and biosynthetic pathway of proline in pigeonpea under drought and there is ample scope for such studies.

3. It is also important to study the interaction between the externally applied plant growth regulators and endogenous hormones and the role of growth regulators and seed hardening chemicals in the manipulation of source-sink relationship.

4. There is a need to understand the basic mechanisms involved in yield improvement through agrochemicals. It is necessary to understand the changes in the genetic make up of the plant due to application of different PGRs and seed hardening chemicals.

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VITA

The author of this thesis Mr. Manish Patidar S/O Shri Rameshwar Patidar was born on 13th July 1988 at Village- Khedi Post- Chandanpuri, Tehsil- Kasrawad, Distt-Khargone (M.P.). He completed his primary and middle school education in native place, and H.S.C. (10th) and H.S.S.C. (12th) Excellence School Khargone M.P.

He joined R.A.K.College of Agriculture, Sehore (M.P.) in 2008-09 and passed B.Sc. (Agriculture) examination in 2012 from Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) with first division (6.86 OGPA). He further joined department of Genetics and Plant Breeding, R.A.K. College of Agriculture, Sehore in 2012-13 and completed his post graduate degree pragramme from Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya Gwalior with first division in 2014.

(Manish Patidar)