

PHYSIOLOGICAL INVESTIGATIONS ON DROUGHT TOLERANCE IN PIGEONPEA (*Cajanus cajan* L.)

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I. INTRODUCTION

Pulses are basic ingredients in the diets of a vast majority of Indian population as they provide a perfect mix of high biological value when supplemented with cereals. Importance of pulses is relatively more in our country as its contribution in nutrient supply is far more than that in Asia and world as a whole. Each plant of a pulse crop is virtually a nature's mini nitrogen fertilizer factory, which enables it to meet its own requirement and also benefit the succeeding crops. In addition, pulses are excellent feed and fodder for livestock. Besides their dietary value and nitrogen fixing ability, pulses also play an important role in sustaining intensive agriculture by improving physical, chemical and biological properties of soil and are considered as excellent crops for diversification of cereal based cropping systems.

The progressive decline in per capita availability of pulses (69 g in 1961 to 30 g in 2002) in India is a matter of great concern. This is attributed to steady marginalization of their cultivation in the wake of "Green Revolution" and burgeoning population with assured supply of cereals at an affordable price. The main focus of policy makers and planners now is on nutritional security. To alleviate protein-energy malnutrition, a minimum of 50 g pulses per capita per day is required in addition to other sources of protein such as cereals, milk, meat, eggs etc. To make up this shortfall in supply and unprecedented population growth, about 20 million tons of pulses are required by 2007, which is expected to touch 28 million tons by 2020 and this can be realized only by adopting recent more productive technologies along with aggressive developmental efforts and favorable government policies (Bangal et. al., 1984).

Pulses occupy 68.32 m ha and contribute 57.51 m tons to the world's food basket. India share 35.2 per cent area and 27.65 per cent of the global production. Per cent contribution of pulses in total food grain production in India has declined during the last three decades. Pulses are grown on 22.24 m ha area, producing 15 m tons. The production of pulses reached its highest (14.91 m tons) during 1999 and there was considerable decline in pulse production during 2000-01 (11.06 m tons). This sudden decline was mainly due to reduction in area under *rabi* pulses, because of early cessation of monsoon and failure of *rabi* rains (Anon., 1998).

Pigeonpea (*Cajanus cajan*) is one of the most important pulse crops of India, which accounts for 90 per cent of the world production, occupying an area of 3.47 m ha with a production of 2.7 m tons and the national average yield is 797 kg/ha. The productivity potential is much lower as compared to wheat (2703 kg/ha), rice (1940 kg/ha), maize (1700-1800 kg/ha), groundnut (913 kg/ha), soybean (1008 kg/ha) and castor (1221 kg/ha) (Nayyar and Malik, 1993). Pigeonpea is the principal pulse crop of North Karnataka and Hyderabad Karnataka region where it is cultivated and is considered as the "Pulse Bowl" of the state and contributes 45 per cent to the total pigeonpea production. It is estimated that the population of the country would be touching nearly 1350 millions by 2020 AD and our minimum pulse requirement would be around 30.3 m tons. On the basis of food characteristic demand system, the demand projections for pulses for the years 2005, 2010 and 2015 are 20.0, 23.3 and 27.0 m tons, respectively. The main challenge in the future scenario will revolve around attaining self-sufficiency in pulses production to meet the increasing demand of protein and ensuring the environmental security (Anon., 1998).

Pulses are mainly grown under agro-ecological constraints such as, cultivation of pulses in rainfed situation as 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 promoters 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.

Pigeonpea is normally cultivated as a rainy crop and is often subjected to water stress at one or several stages of crop growth and development, since it is a long duration crop. 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.

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 investigations were carried out with the following objectives;

- 1) To study the role of plant growth regulators viz., NAA, miraculan cytozyme and triacontanol in increasing the retention of flowers and fruit set at different stages of crop growth
- 2) To study the role of agro-chemicals for drought induction and enhancing productivity in pigeonpea
- 3) To study the influence of plant growth regulators and agro-chemicals on biochemical changes

II. REVIEW OF LITERATURE

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 research 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, biochemical 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 MORPHOPHYSIOLOGICAL 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).

Mehrotra *et.al.*, (1970) observed a reduction of plant height in okra by the application of cycocel either to soil at three leaf stage or by soaking the seeds in 100 ppm for 24 hours. They also found a delay in flowering by soaking the seeds with cycocel as compared to soil application. Soil application of cycocel did not affect the number of leaves, while soaking seeds in cycocel (250 mg/l) significantly increased the number of leaves in tomato (Linkens *et.al.*, 1964). Similar results were obtained by Arora *et.al.*, (1990) with cycocel (100 ppm) both as seed and foliar treatments. Singh *et.al.*, (1975) indicated that, pre sowing seed hardening in barley helped the seeds to germinate a day earlier than the unsoaked seeds leading to early growth of the crop. The grain and straw yield was also significantly increased with soaked seeds than with the unsoaked seeds. Use of miraculan (triacantanol) increased the growth in *in vitro* of cell cultures of haploid tobacco. The fresh weight of cell cultures of tomato, potato, beans and barley was also found to increase (Hangarter *et.al.*, 1978).

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. The treatment with triacantanol increased the plant growth (root and stem) in pea (Henry and Gordon, 1980).

Raffique-Uddin (1984) noticed that foliar spray of CCC at 0, 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. 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 of $\text{Ca}(\text{OH})_2$ 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 which were significantly superior over control. Similarly, seed treatment with CaCl_2 (2%) in the ratio of 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) observed that foliar spray of ascorbic acid, NAA and GA increased the vegetative growth and assimilate production and favoured longer reproductive growth in greengram. 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). Similarly, Arora *et.al.*, (1988) studied the effect of cytozyme (0.2%) and indicated that it promoted increase in height of potato plant. The maximum plant height in turnip was noticed with 150 ml/ha of cytozyme. While, 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. Seed priming with mixtalol (6 ppm) for six hours at 25°C increased the activities of phosphoenol pyruvate carboxylase, NAD^+ malate dehydrogenase, NAD maleic enzyme and hence faster radicle emergence under drought stress condition in pigeonpea (Nayyar and Malik, 1992). Similarly, Rao and Khanna (1992) noticed that foliar spray of mixtalol did not show any significant effect on days to 75 per cent heading and maturity. But it increased the plant height, 100 - grain weight as compared to control in triticale.

Singh and Kakralya (1992) reported that pre sowing seed soaking with 50 mg/l of ethrel or GA or benzyl adenine treatments for 12 hours, increased the germination per cent, crop stand, seedling growth and yield in pigeonpea. In another study of Subramanian and Janardhanan (1992) observed that lower concentration of cytozyme promoted seed germination, seedling growth, fresh and dry weight and chlorophyll pigments in pigeonpea. The higher concentration inhibited seed germination as well as seedling growth.

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 treated seeds performed better than water treated or untreated seeds in terms of germination per cent, vigour index, germination relative index, mean length of roots and shoots and seedling dry weight under drought stress conditions.

Similarly, 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°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. While, Lakshamma 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 finger millet. 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. Whereas, Govindan and Thirumurugan (2000) revealed that the growth parameters like plant height, LAI and dry matter production in greengram were significantly higher with foliar treatments of KNO_3 (1%) or KCl (1%) and their combinations.

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. On the other hand, Bhattacharya and Sharma (2001) found that leaf area and total dry matter during flowering are major traits to restrict flower drop under normal and under 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. Jayaramireddy (2001) observed that among 10 genotypes tested, the genotype LRG 30 recorded the maximum plant height and relative water content (RWC) as compared to other genotypes under drought in pigeonpea. The foliar application of triacontanol (0.2 %) at vegetative, flowering and podding stages significantly increased the plant height, 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 the nodule number, nodule volume, dry weight of the plants and total nitrogen content as compared to control. While, Garai and Datta (2003) indicated that foliar application of cycocel reduced the plant height; increased the number of branches and nodules per plant in greengram. Hardening as well as hardening and pelleting treatments enhanced seed germination and seedling vigour as compared to control in blackgram (Begum and Krishnasamy, 2003). Prakash *et.al.*, (2003) noticed that the foliar application of planofix (30 ppm) at 30 and 45 DAS and chatmatkar (120 ppm) at 60 DAS recorded increased plant height, LAI and SLW in blackgram. Foliar spray of ZnSO_4 (0.5%) increased the plant height, number of leaves and branches per plant significantly over other treatments in pigeonpea (Varma *et.al.*, 2004).

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. 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). Similarly, 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.

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. (Krishnamurthy *et. al.*, 1973).

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 Sakharam 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.

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 (Kalubarme and Pandey, 1979). 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 (Kalubarme and Pandey, 1979). 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. In another study, 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. Henry and Gordon (1980) noticed that the treatment of triacontanol to pea increased the plant growth like root and stem biomass.

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 $\text{Ca}(\text{OH})_2$ 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. Arjunan and Srinivasan (1989) showed that seed hardening treatment of groundnut with CaCl_2 (1.0%) gave significantly higher pod yield through increased germination per cent and higher dry matter accumulation. 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. Baghel and Yadav (1992) observed that the foliar application NAA (30 ppm) increased specific leaf area (SLA) in soybean. Nayyar and Malik (1993) revealed that mixtalol treated seeds performed better germination relative index, mean

length of roots and shoots and dry matter accumulation by seedlings under drought stress conditions. Similarly, foliar application of mixtalol significantly increased dry matter per plant followed by vipul (triacontanol) in blackgram (Shah *et.al.*, 1994). Dashora and Jain (1994) also indicated that spraying of triacontanol significantly increased LAI by 27.9 per cent in soybean. In another study, 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. Similarly 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 (Lakshamma and Rao, 1996). Similarly, Jayarami Reddy *et.al.*, (1996) reported that foliar spray of NAA (10 ppm) + KNO₃ (0.5%) and NAA (20 ppm) + KNO₃ (0.5%) recorded the maximum dry matter production in pigeonpea as compared to control.

NargisJahan *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% CaCl₂, 100 ppm KH₂PO₄ and 100 ppm Na₂HPO₄) on growth in finger millet and found that the treatment with Na₂HPO₄ (100 ppm) caused a remarkable improvement in growth attributes such as LAI, LAD, CGR and dry matter accumulation at different growth stages. Similarly, 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 KNO₃ (1%) or KCl (1%) and their combination.

Punithavathi and Palaniswamy (2001) indicated that ragi seeds soaked in 1% concentration of KCl and CaCl₂, 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 podding stages significantly increased the biomass production and better dry matter partitioning towards the sink in mungbean (Jayaramireddy *et.al.*, 2002). In another study, 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. According to Sumeria (2003), the application of 60 kg P/ha and triacontanol granules at 30 kg/ha significantly increased growth parameters in mustard. Ramarao (2004) when evaluated the genotypes of pigeonpea for adaptation to drought under natural condition found that ICPL 85063 possessed higher SLA and drymatter. 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. Similarly, Thakare *et.al.*, (2006) found that foliar application of NAA (50 ppm) significantly increased the dry weight of pods per plant in soybean.

2.3 EFFECT OF SEED HARDENING CHEMICALS AND FOLIAR SPRAYS OF AGROCHEMICALS ON YIELD AND YIELD COMPONENTS

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. Investigations made by Appleby *et. al.*, (1966) revealed an increase in test weight and grain yield of wheat with 5 per cent 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%) 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 was 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. Seed soaking of wheat in 0.5 % cycocel prior to sowing increased the grain yield (De *et. al.* 1982). 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.

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 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. Similarly, 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 compared to control. Similarly, 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. Arjunan and Srinivasan (1989) noticed that the seed hardening treatment of groundnut with CaCl_2 (1%) significantly increased the mean pod yield by 20 per cent over untreated control. While, Sharma *et. al.* (1989) stated that foliar spray of NAA improved yield and its components significantly over control in mungbean. In another study, 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. Similarly, Sud and Parmar (1990) revealed that foliar application of triacontanol had a profound effect on the size and quality of apricot fruits and fruit weight increased significantly in comparison to control. 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%). Shinde *et al.*, (1991) observed that foliar spray of growth regulators (NAA and ethep) 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 compared to water treated or untreated seeds in terms of mean length of shoots and dry matter accumulation and yield under drought stress condition. Similarly, foliar application of mixtalol significantly increased the dry matter per plant and yield followed by vipul in blackgram (Shah *et al.*, 1994). In another study, 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, seed 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. Similarly, 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. Similarly, 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 increase 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. Similarly, Shukla *et al.*, (1997) indicated that double sprays of triacontanol enhanced the biomass, pod weight per plant and ultimately resulting in enhanced seed yield. In another study, 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. Similarly, Govindan and Thirumuragan (2000) observed that the foliar spray of KCl (1 %) + KNO₃ (1%) to increase the grain yield of greengram by 21.8 per cent over control. 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 KCl (1%) at terminal drought stress. 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 blackgram. Similarly, 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 K₂HPO₄ (2%) followed by KCl (2%) and KH₂PO₄ (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 podding stages significantly increased seed yield in mungbean grown under rainfed condition. In another study, 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. Combined foliar application of planofix (30 ppm) at 30 and 45 DAS and chatmatkar (120 ppm) at 60 DAS recorded increased number of pods per plant, number of seeds per plant, 100 seed weight and yield in blackgram (Prakash *et al.*, 2003). Similarly, Kalpana and Krishnarajan (2003) reported increased the 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 CaCl₂ (2%) in chickpea. Foliar application of ZnSO₄ (0.5%) significantly increased seed yield and its attributes over other treatments in pigeonpea (Varma *et al.*, 2004). According to Patil *et al.*, (2005), spraying NAA (25 ppm) resulted in significantly higher seed yield through increased flower production, clusters per plant, pod set per cent, pods per plant and 100 seed weight in mungbean. In another study 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.

III. MATERIAL AND METHODS

Field experiments were conducted during *kharif* 2004-05 and 2005-06 to study the effect of seed hardening, use of agro chemicals and nutrients on terminal flower drop and drought tolerance in pigeonpea. The details of materials used and techniques adopted during the course of investigation are described in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted on medium black clay soil (Plot no. 126 A of 'E' block) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, which is situated at 15° 12' N latitude and 75° 07' E longitude with an altitude of 678 m above the mean sea level.

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 CLIMATIC CONDITIONS

The meteorological data during the crop growth period (2004-05 and 2005-06) and the average of last 54 years (1950-2004) are presented in Table 1. The total rainfall during 2004-05 was 729.0 mm while during 2005-06, it was 1075.4 mm. The maximum temperature during crop growth period ranged from 27.0 °C (August) to 30.9 °C (June) during 2004-05 and from 27.1 °C (August) to 29.9 °C (January) during 2005-06. The minimum temperature during 2004-05 ranged from 12.5 °C (December) to 21.5 °C (June), while during 2005-06, it was 12.9 °C (January) to 21.0 °C (July), whereas, the temperature data of last 54 years indicated that November month recorded the lowest temperature (13.44 °C).

The relative humidity ranged from 45.0 per cent (December) to 83.0 per cent (August) during 2004-05 and 51.0 per cent (November) to 85.0 per cent (September) during 2005-06. Whereas, during 1950-2004, it ranged from 51.0 per cent (January) to 86.0 per cent (July).

3.3 SOIL AND ITS CHARACTERISTICS

The experimental site consisted of medium black clay loam soil. The composite soil samples were analysed for their physical and chemical properties as per the procedure of Piper (1966) and Jackson (1967), and the details are furnished in Table 2.

Table 1. Monthly meteorological data during crop growth period (*kharif* 2004-05 and 2005-06) and the average of 54 years (1950-2004) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Months	2004-05				2005-06				1950-2004			
	Temperature ($^{\circ}\text{C}$)		Mean relative humidity (%)	Rainfall (mm)	Temperature ($^{\circ}\text{C}$)		Mean relative humidity (%)	Rainfall (mm)	Temperature ($^{\circ}\text{C}$)		Mean relative humidity (%)	Rainfall (mm)
	Max.	Min.			Max.	Min.			Max.	Min.		
June	30.9	21.5	76	151.0	30.9	21.5	76	151.0	22.06	20.95	87	145.7
July	29.2	21.0	79	24.8	27.4	21.0	83	290.2	22.01	20.62	86	95.3
August	27.0	20.3	83	160.7	27.1	20.4	81	138.8	28.75	20.16	82	100.5
September	28.6	19.9	77	222.1	27.5	20.3	85	194.5	30.12	19.30	76	130.9
October	30.1	18.4	65	64.6	29.6	19.1	70	89.4	29.46	15.50	68	32.0
November	30.2	15.9	52	0.6	29.4	14.9	51	38.0	29.18	13.44	63	54.5
December	29.4	12.5	45	0.0	28.9	13.1	53	0.0	29.15	19.23	63	0.08
January	30.7	15.0	49	0.8	29.9	12.9	52	0.0	34.52	16.02	51	1.16
February	33.2	16.3	43	0.0	32.4	14.8	39	0.0	35.73	18.81	56	0.14
March	36.0	18.9	42	0.0	34.1	18.1	45	5.2	37.00	21.32	76	48.4
April	36.3	21.3	53	75.0	37.1	20.3	49	1.5	36.52	21.48	66	81.4
May	37.0	21.5	55	29.4	35.3	20.9	61	166.8	29.50	21.21	81	109.1
Total				729.0				1075.4				799.5

3.4 EXPERIMENTAL DETAILS

Treatment Details

T ₁	- Seed hardening with CaCl ₂ (2%)
T ₂	. Seed hardening with MgSO ₄ (100 ppm)
T ₃	. Seed hardening with ZnSO ₄ (100 ppm)
T ₄	. Seed hardening with KH ₂ PO ₄ (1%)
T ₅	. Seed hardening with CCC (100 ppm)
T ₆	. Seed hardening with KCl (100 ppm)
T ₇	. Seed hardening with ascorbic acid (20 ppm)
T ₈	. Seed hardening with cobalt nitrate (1000 ppm)
T ₉	. Seed hardening with sodium molybdate (100 ppm)
T ₁₀	. Seed hardening with mixtalol (10 ppm)
T ₁₁	. Foliar application of MgSO ₄ (0.5%) at 70 & 90 DAS
T ₁₂	. Foliar application of CCC (500 ppm) at 70 & 90 DAS
T ₁₃	. Foliar application of NAA (20 ppm) at flowering and fruit set
T ₁₄	. Foliar application of NAA (40 ppm) at flowering and fruit set
T ₁₅	. Foliar application of triacontanol (20 ppm) at flowering and fruit set
T ₁₆	. Foliar application of miraculan (2.0 ml/l) at flowering and fruit set
T ₁₇	. Foliar application of cytozyme (2.0 ml/l) at flowering and fruit set
T ₁₈	. Foliar application of APSA (1.0 ml/l) at flowering and fruit set
T ₁₉	. Foliar application of APSA (2.0 ml/l) at flowering and fruit set
T ₂₀	. Control

Spacing	: 90 cm x 20 cm
Genotype	: ICPL-87119
Plot size	: 10.8 m ²
Date of sowing	: 18-6-2004 and 05-07-2005
Design	: Randomised Block Design (RBD)
Fertilizer application	: 25:50:N:P ₂ O ₅ kg/ha
Replications	: Three

The recommended dose of nitrogen and phosphorous per hectare was applied in the form of urea and single super phosphate (SSP), respectively. The nitrogen was given in two equal split doses.

3.5 CULTURAL OPERATIONS

3.5.1 Land preparation

Land was prepared by deep summer ploughing, followed by clod crushing and repeated harrowings. The land was smoothened with a plank to bring the soil to a fine tilth suitable for sowing. The treatments were laid out according to the plan given in figures 1 and 2.

Table 2. Physical and chemical properties of soil from the experimental site

Sl. No.	Properties	Value obtained	Method employed
I.	Physical properties		
1.	Coarse sand (%)	6.28	International pipette method (Piper, 1966)
2.	Fine sand (%)	14.27	International pipette method (Piper, 1966)
3.	Silt (%)	27.52	International pipette method (Piper, 1966)
4.	Clay (%)	51.99	International pipette method (Piper, 1966)
5.	Bulk density (g/cc)	1.33	Core sample method (Dastane, 1967)
II.	Chemical properties		
1.	Soil pH (1:2.5 soil:water)	7.60	pH meter (Piper, 1966)
2.	Electrical conductivity (dS/m)	0.28	Conductivity bridge (Jackson, 1967)
3.	Organic carbon (%)	0.52	Walkley and Black wet oxidation method (Jackson, 1967)
4.	Available nitrogen (kg/ha)	221.0	Modified Kjeldahl method (Jackson, 1967)
5.	Available phosphorus (kg/ha)	32.4	Olsen's method (Jackson, 1967)
6.	Available potassium (kg/ha)	318.7	Flame photometer (Jackson, 1967)



Plate 1. General view of the Experimental Plot

LEGEND

T ₁	- Seed hardening with CaCl ₂ (2%)
T ₂	. Seed hardening with MgSO ₄ (100 ppm)
T ₃	. Seed hardening with ZnSO ₄ (100 ppm)
T ₄	. Seed hardening with KH ₂ PO ₄ (1%)
T ₅	. Seed hardening with CCC (100 ppm)
T ₆	. Seed hardening with KCl (100 ppm)
T ₇	. Seed hardening with ascorbic acid (20 ppm)
T ₈	. Seed hardening with cobalt nitrate (1000 ppm)
T ₉	. Seed hardening with sodium molybdate (100 ppm)
T ₁₀	. Seed hardening with mixtalol (10 ppm)
T ₁₁	. Foliar application of MgSO ₄ (0.5%) at 70 & 90 DAS
T ₁₂	. Foliar application of CCC (500 ppm) at 70 & 90 DAS
T ₁₃	. Foliar application of NAA (20 ppm) at flowering and fruit set
T ₁₄	. Foliar application of NAA (40 ppm) at flowering and fruit set
T ₁₅	. Foliar application of triacontanol (20 ppm) at flowering and fruit set
T ₁₆	. Foliar application of miraculan (2.0 ml/l) at flowering and fruit set
T ₁₇	. Foliar application of cytozyme (2.0 ml/l) at flowering and fruit set
T ₁₈	. Foliar application of APSA (1.0 ml/l) at flowering and fruit set
T ₁₉	. Foliar application of APSA (2.0 ml/l) at flowering and fruit set
T ₂₀	. Control

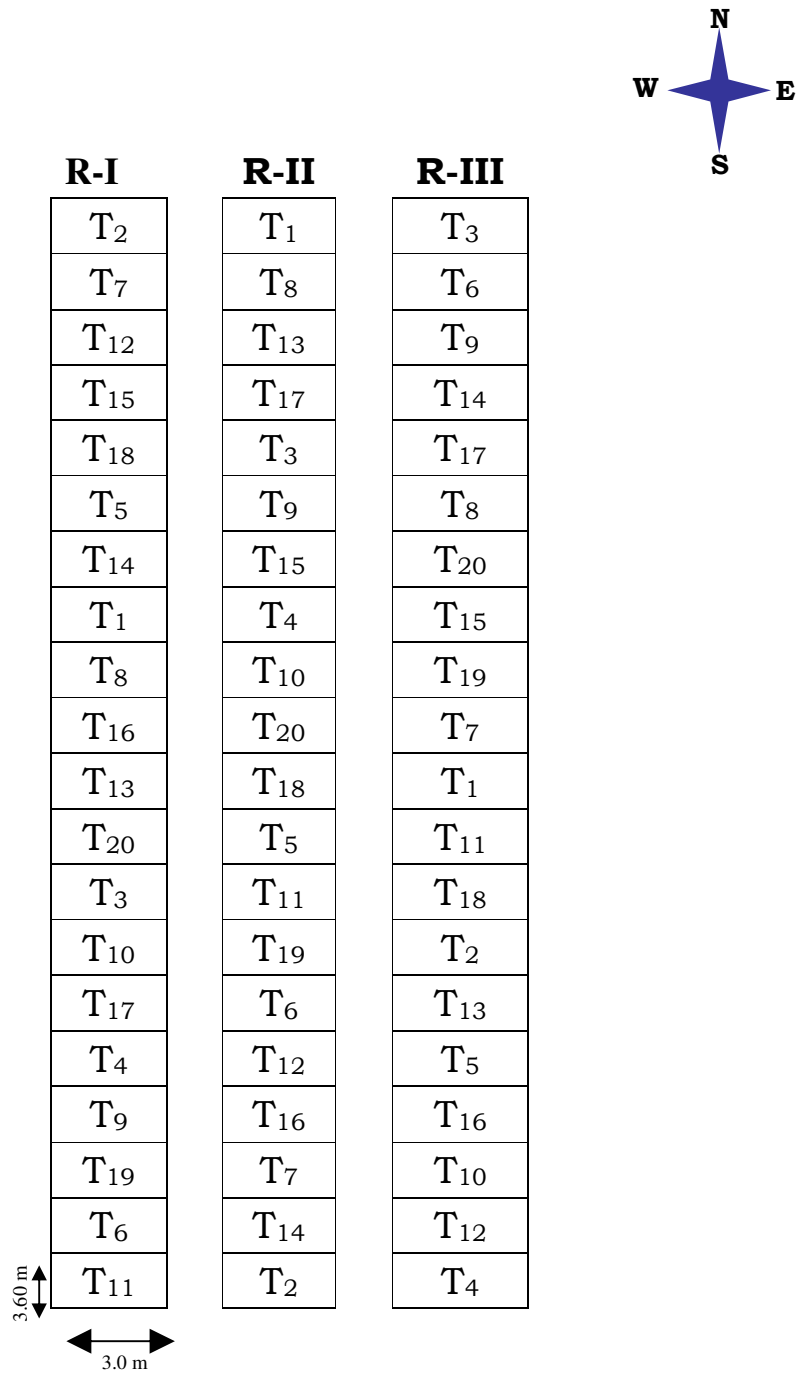


Fig. 1. PLAN OF LAYOUT OF THE EXPERIMENT (KHARIF, 2004-05)

LEGEND

T ₁	- Seed hardening with CaCl ₂ (2%)
T ₂	. Seed hardening with MgSO ₄ (100 ppm)
T ₃	. Seed hardening with ZnSO ₄ (100 ppm)
T ₄	. Seed hardening with KH ₂ PO ₄ (1%)
T ₅	. Seed hardening with CCC (100 ppm)
T ₆	. Seed hardening with KCl (100 ppm)
T ₇	. Seed hardening with ascorbic acid (20 ppm)
T ₈	. Seed hardening with cobalt nitrate (1000 ppm)
T ₉	. Seed hardening with sodium molybdate (100 ppm)
T ₁₀	. Seed hardening with mixtalol (10 ppm)
T ₁₁	. Foliar application of MgSO ₄ (0.5%) at 70 & 90 DAS
T ₁₂	. Foliar application of CCC (500 ppm) at 70 & 90 DAS
T ₁₃	. Foliar application of NAA (20 ppm) at flowering and fruit set
T ₁₄	. Foliar application of NAA (40 ppm) at flowering and fruit set
T ₁₅	. Foliar application of triacontanol (20 ppm) at flowering and fruit set
T ₁₆	. Foliar application of miraculan (2.0 ml/l) at flowering and fruit set
T ₁₇	. Foliar application of cytozyme (2.0 ml/l) at flowering and fruit set
T ₁₈	. Foliar application of APSA (1.0 ml/l) at flowering and fruit set
T ₁₉	. Foliar application of APSA (2.0 ml/l) at flowering and fruit set
T ₂₀	. Control

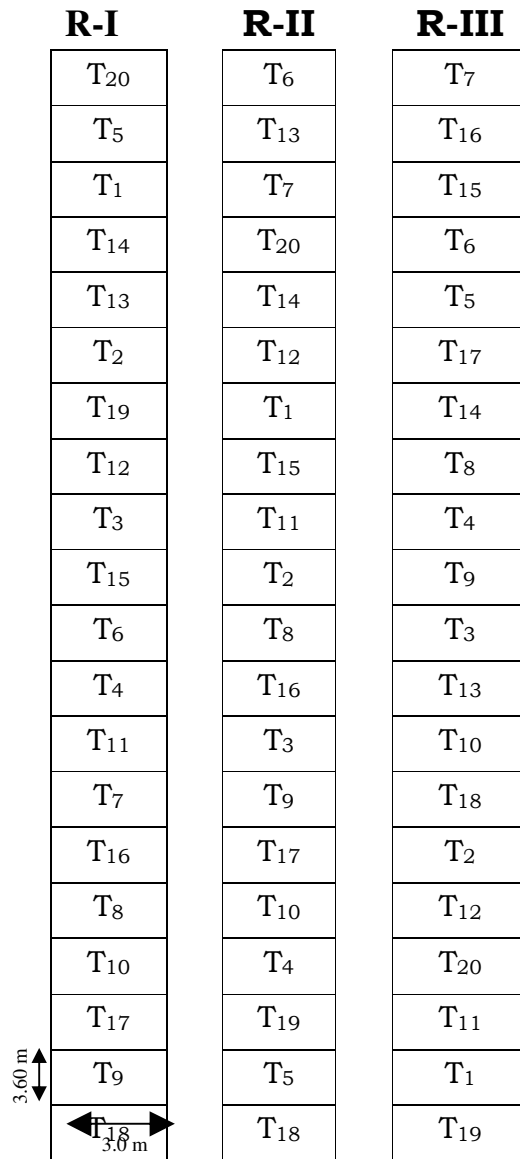


Fig. 2. PLAN OF LAYOUT OF THE EXPERIMENT (KHARIF, 2005-06)

3. 5.2 Seed treatment and sowing

A day before sowing the pigeonpea seeds were soaked separately in CaCl_2 (2%), MgSO_4 (100 ppm), ZnSO_4 (100 ppm), KH_2PO_4 (1.0%), CCC (100 ppm), KCl (100 ppm), ascorbic acid (20 ppm), cobalt nitrate (1000 ppm), sodium molybdate (100 ppm) and mixtalol (10 ppm) for six hours and the seeds were dried under shade and used for sowing.

3. 5. 3 Treatment imposition

Foliar application of growth regulators at different concentrations was done at flowering and fruit set stages.

3. 5. 4 Plant protection chemicals

To control the pest and diseases the crop was sprayed with endosulfon 2.0 ml/l mixed and sprayed at flowering stage and subsequently three more sprays were given at the interval of 15 days.

3.5.5 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 m^{-2} was computed.

3.6 COLLECTION OF EXPERIMENTAL DATA

Five plants at random from each plot were selected and tagged for the purpose of recording morphological, physiological, biochemical and yield parameters at 70, 90 DAS and at harvest.

3.6.1 Plant height (cm)

Plant height was recorded from the ground level to the growing tip of the main shoot. Measurements were taken from five tagged plants in each treatment and the average height was calculated and expressed in centimeters.

3.6.2 Plant spread (cm^2)

The plant spread was worked out by measuring the canopy spread in two directions i.e., in between the rows and in between the plant within the row, length and breadth of canopy cover were multiplied and expressed in cm^2 .

3.6.3 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.

3.6.4 Days to pod initiation

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

3.6.5 Growth analysis

3.6.5.1 Leaf area ($\text{dm}^2 \text{ plant}^{-1}$)

The leaves from plants selected for growth analysis from each treatment were used for the estimation of leaf area. Leaf area was computed by graphical method and expressed as $\text{dm}^2 \text{ plant}^{-1}$.

3.6.5.2 Leaf area index (LAI)

The Leaf area index was calculated by dividing the leaf area per plant by the land area occupied by the plant (Sestak *et al.*, 1971).

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Land area}}$$

3.6.5.3 Crop growth rate (CGR)

Crop growth rate is the rate of dry matter produced per unit ground area per unit time (Watson, 1952). It was calculated by using the following formula and expressed as $\text{g dm}^{-2} \text{ day}^{-1}$,

$$\text{CGR} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{A}$$

where,

W_1 = Dry weight of the plant (g) at time t_1

W_2 = Dry weight of the plant (g) at time t_2

t_1 & t_2 = Time interval (days)

A = Unit land area (dm^2)

3.6.5.4 Relative growth rate (RGR)

It is the rate of increase in the dry weight per unit dry weight already present and expressed as $\text{g g}^{-1} \text{ day}^{-1}$ (Radford, 1967). RGR was calculated by using the following formula.

$$\text{RGR} = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

where,

W_1 = Dry weight of the plant at time t_1

W_2 = Dry weight of the plant at time t_2

t_1 & t_2 = Time interval in days

3.6.5.5 Net assimilation rate (NAR)

It is the rate of dry weight increase per unit leaf area per unit time (Radford, 1967). It is expressed as $\text{mg dm}^{-2} \text{ day}^{-1}$ and calculated as,

$$\text{NAR} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log_e A_2 - \log_e A_1)}{(A_2 - A_1)}$$

Where,

A_1 & W_1 = Leaf area (dm^2) and dry weight of the plant (g), respectively at time t_1

A_2 & W_2 = Leaf area (dm^2) and dry weight of the plant (g), respectively at time t_2

t_1 & t_2 = Time interval in days

3.6.5.6 Specific leaf area (SLA)

The inverse of the specific leaf weight is the specific leaf area (cm^2/mg) and was calculated by using the following formula.

$$\text{SLA} = \frac{\text{Leaf area (dm}^2\text{)}}{\text{Leaf dry weight (g)}}$$

3.6.5.7 Specific leaf weight (SLW)

The specific leaf weight indicates the leaf thickness and was determined by the formula of Radford (1967) and expressed as mg dm^{-2} .

$$\text{SLW} = \frac{\text{Leaf dry weight (g)}}{\text{Leaf area (dm}^2\text{)}}$$

3.6.5.8 Leaf area duration (LAD)

Leaf area duration is the integral of leaf area index (LAI) over the growth period (Watson, 1952). LAD was worked out as per the formula of Power *et al.*, 1967 and expressed in days.

$$\text{LAD} = \frac{(L_i - L_{(i+1)})}{2} \times (t_2 - t_1)$$

where,

L_i = LAI at i^{th} stage

$L_{(i+1)}$ = LAI at $(i+1)^{\text{th}}$ stage

t_1 & t_2 = Time interval between i and $(i + 1)$ stage (days).

3.6.5.9 Biomass duration (BMD)

The biomass duration was calculated as given by Sestak *et al.* (1971) and expressed in g days.

$$\text{BMD} = \frac{(\text{TDM}_i - \text{TDM}_{(i+1)})}{2} \times (t_2 - t_1)$$

where,

TDM_i = Total dry matter at i^{th} stage

$\text{TDM}_{(i+1)}$ = Total dry matter at $(i+1)^{\text{th}}$ stage

t_1 & t_2 = Time interval between i and $(i + 1)$ stage (days)

3.6.5.10 Absolute growth rate (AGR)

It is the dry matter production per unit time (g day^{-1}) and was calculated by using the following formula,

$$\text{AGR} = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

where,

W_1 = Dry weight of the plant at time t_1

W_2 = Dry weight of the plant at time t_2

t_1 & t_2 = Time interval in days

3.6.6 Yield and yield components

3.6.6.1 Number of pods per plant

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

3.6.6.2 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.

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

3.6.6.3 Seed yield (g/plant)

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

3.6.6.4 Seed yield (kg ha^{-1})

Seed yield obtained from each net plot area was used for calculating seed yield per ha.

3.6.6.5 Total dry matter production

Randomly selected five plant samples were separated and dried in oven at 80°C until constant weight was obtained. Total dry matter was calculated and expressed as grams per plant at different intervals of crop growth period.

3.6.6.6 Seed number per pod

The number of seeds per pod was calculated based on total number of pods and seeds present in five randomly selected plants and the average was worked out.

3.6.6.7 100 - Seed weight

100-grains at random were collected from net plot yield and the weight (g) was recorded on electric balance.

3.6.6.8 Harvest index

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

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

3.7 BIOCHEMICAL PARAMETERS

3.7.1 Estimation of chlorophyll content

The chlorophyll pigments viz., chlorophyll 'a', chlorophyll 'b' and total chlorophyll content in leaf were determined by dimethyl sulfoxide method (DMSO) of Hiscox and Israelstam (1971). Top fully expanded leaf was brought in polyethylene bags kept in ice box from the field and was cut into small pieces. Known weight of leaves (100 mg) was kept in test tubes containing 7.0 ml of dimethyl sulfoxide (DMSO). The test tube incubated at 65°C for 30 minutes. Leaf residue was removed by decanting the solution and final volume was made to 10 ml with DMSO. The absorbance of the extract was measured at 645, 652 and 663 nm in a UV-Vis spectrophotometer (Elico, SL-159) and a blank was run using DMSO.

The total chlorophyll, chlorophyll 'a' and chlorophyll 'b' contents were calculated by using the following formula and expressed in mg g fresh weight⁻¹.

$$\text{Chlorophyll 'a' (mg g}^{-1} \text{ fr. wt.)} = \frac{12.7(A_{663}) - 2.69(A_{645}) \times V}{1000 \times w \times a}$$

$$\text{Chlorophyll 'b' (mg g}^{-1} \text{ fr. wt.)} = \frac{22.9(A_{645}) - 4.68(A_{663}) \times V}{1000 \times w \times a}$$

$$\text{Total Chlorophyll (mg g}^{-1} \text{ fr. wt.)} = \text{Chlorophyll 'a' + Chlorophyll 'b'}$$

Where,

A₆₄₅ = Absorbance of the extract at 645 nm

A₆₆₃ = Absorbance of the extract at 663 nm

a = Path length of Cuvette (1 cm)

V = Final volume of the chlorophyll extract (10 ml)

w = Fresh weight of the sample (0.10 g)

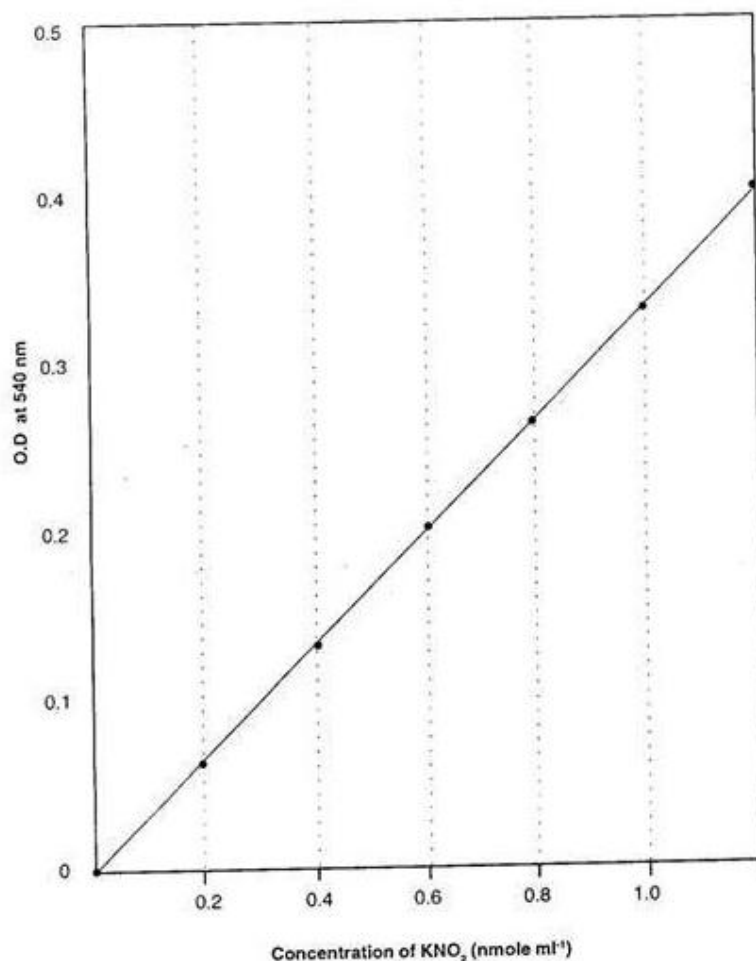


Fig 3. Standard curve for nitrate reductase activity

3.7.2 Estimation of nitrate reductase activity

Nitrate reductase activity was assayed in leaves by the method of Sardhambal *et al.* (1978) at 90 and 120 DAS. A 0.5 g of fresh leaf sample was cut into small pieces and placed in petridish containing 0.1 M KNO₃ under bright sunlight for 1 hour and then placed in a solution containing 2.0 ml of 0.2 M phosphate buffer, 0.5 ml of 0.02 M KNO₃ and 2.5 ml of 5 per cent propanol and kept in dark for incubation for 30 minutes at 30° C. To which, 0.1 ml zinc acetate (1.0 M) and 1.9 ml of ethanol (70%) were added to terminate the reaction. The contents were centrifuged at 3000 g for 10 minutes and the supernatant was collected. To this, 1.0 ml of sulphanilamide (1%) and 1 ml of NNEDA (0.02%) were added and incubated at room temperature for 20 minutes. The pink colour developed was read at 540 nm in a spectrophotometer. Nitrate reductase activity was calculated from KNO₂ standard curve and expressed in μ mole of NO₂ formed per gram fresh weight per hour.

3.7.3 Estimation of free proline

Free proline content was estimated by following the method of Bates *et al.*, (1973). A known weight (0.5 g) of fresh leaf sample was macerated in a mortar using 10 ml of 3 per cent sulphosalicylic acid. The extract was filtered and 2.0 ml of the filtrate was used for proline estimation. To this 2.0 ml of filtrate, 2.0 ml of acid ninhydrin reagent (2.5 g of ninhydrin dissolved in 40 ml of 6.0 M orthophosphoric acid and 60 ml of glacial acetic acid), 2.0 ml of glacial acetic acid were added and placed in boiling water bath for one hour. Following this, test tubes containing the samples were transferred to an ice bath for cooling. The contents of

each test tube were transferred to a separatory funnel and 6.0 ml of toluene was added, shaken thoroughly and allowed for few minutes for separation of two layers. The lower layer was discarded and the upper toluene layer containing the colour complex was taken into a test tube. The optical density was read at 520 nm using spectrophotometer (Elico, SL-159 UV-vis spectrophotometer) and the proline content was calculated as follows.

$$\text{Proline content } (\mu\text{g} / \text{g dry wt}) = \frac{36.2311 \times \text{OD} \times V \times d}{2 \times f}$$

where,

- OD = Optical density at 520 nm
- V = Total volume of the extract in ml
- d = Fresh weight / dry weight ratio
- f = Fresh weight taken for proline estimation (mg)
- 2 = Volume of extract taken for proline estimation.

3.7.4 Relative water content (RWC)

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 72^o C for 48 hours, the dry weight was recorded and RWC was calculated by using the following formula

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

3.8 STATISTICAL ANALYSIS

The data were subjected to the analysis of variance by following the method of Panse and Sukhatme (1967). The level of significance used in 'F' and 't' tests was P = 0.05. Critical differences were calculated wherever 'F' test was found significant.

3.9 ECONOMICS

Additional cost involved and returns obtained by applying different plant growth regulators and agrochemicals was worked out on the basis of yield potential, cost of chemicals, cost of cultivation and other details per hectare basis.

IV. EXPERIMENTAL RESULTS

Field experiments were conducted during *kharif* 2004 and 2005 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, to study the influence of plant growth regulators and seed hardening chemicals on various morphological, physiological, biochemical and yield parameters in pigeonpea (*Cajanus cajan*). The results obtained from the investigation are presented in this chapter.

4.1 MORPHOLOGICAL CHARACTERS

4.1.1 Plant height (cm)

The data on plant height as influenced by seed hardening chemicals and growth regulators showed significant differences among the treatments during both the years (Table 3 and 4). In general, the plant height increased from 45 DAS to harvest during both the years (2004-05 and 2005-06). However the plant height was more during 2005-06. The effect of plant growth regulators was more pronounced as compared to seed hardening treatments. During both the years, the treatment miraculan (2 ml/l) registered significantly higher plant height followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) as compared to control. However, the lowest plant height was observed with CCC (100 ppm) during both the years.

4.1.2 Plant spread (cm²)

The plant spread indicated significant differences between the treatments during both the years. (Table 5 and 6). In general, the plant growth regulators recorded significantly higher plant spread compared to seed hardening chemicals.

During first year (2004-05), the treatment miraculan (2.0 ml/l) recorded significantly higher plant spread followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l). Among the seed hardening chemicals, CCC (100 ppm) registered higher plant spread followed by mixtalol (10 ppm) and sodium molybdate (100 ppm) at 90 DAS and at harvest. However, the plant spread was low in control.

Whereas during second year (2005-06), a similar trend was observed. However, among the PGR'S miraculan (2.0 ml/l) recorded significantly higher plant spread followed by NAA (40 ppm) and NAA (20 ppm); among the seed hardening treatments, CCC (100 ppm), mixtalol (10 ppm) and sodium molybdate (100 ppm) registered higher plant spread. The least plant spread was recorded in control.

4.1.3 Days to flower initiation

The number of days to flower initiation as influenced by plant growth regulators and seed hardening chemicals at different stages in both the years showed significant differences among the treatments (Table 7 and 8). In general, seed hardening chemicals took lesser days to flower initiation compared to plant growth regulators.

During 2004-05, the treatment with CaCl₂ (2 %) registered lesser number of days to flower initiation (77.2) followed by MgSO₄ (100 ppm), ascorbic acid (20 ppm), KH₂PO₄ (1 %) and CCC (100 ppm). Among the plant growth regulators the treatment miraculan (2.0 ml/l) recorded lesser number of days to flower initiation followed by APSA (1.0 ml/l), triacontanol (20 ppm), MgSO₄ (100 ppm), CCC (100 ppm) and KH₂PO₄ (1 %). Among the plant growth regulators the treatment with miraculan (2.0 ml/l) recorded lesser number of days to flower initiation followed by NAA (20 ppm), APSA (1.0 ml/l), triacontanol (20 ppm) and APSA (2.0

Table 3. Effect of seed hardening and agrochemicals on plant height (cm) at different stages in pigeonpea (2004-05)

Treatment	Days after sowing			
	45	90	120	At harvest
T ₁ - CaCl ₂ (2%)	57.0	132.6	165.7	180.3
T ₂ - MgSO ₄ (100 ppm)	54.6	131.0	163.8	178.2
T ₃ - ZnSO ₄ (100 ppm)	54.1	131.3	164.2	178.0
T ₄ - KH ₂ PO ₄ (1%)	54.7	132.1	165.1	182.9
T ₅ - CCC (100 ppm)	55.1	133.2	166.5	183.4
T ₆ - KCl (100 ppm)	56.2	128.4	160.5	182.2
T ₇ - Ascorbic acid (20 ppm)	54.2	125.8	157.3	184.9
T ₈ - Cobalt nitrate (1000 ppm)	53.7	124.8	156.0	183.9
T ₉ - Sodium molybdate (100 ppm)	55.4	123.8	154.7	185.7
T ₁₀ - Mixtalol (10 ppm)	55.6	132.6	165.7	186.8
T ₁₁ - MgSO ₄ (0.5%)	53.3	130.5	163.1	187.3
T ₁₂ - CCC (500 ppm)	49.1	120.2	148.0	168.9
T ₁₃ - NAA (20 ppm)	53.4	141.6	177.1	190.3
T ₁₄ - NAA (40 ppm)	54.8	143.0	178.7	193.6
T ₁₅ - Triacantanol (20 ppm)	55.1	139.9	174.9	187.7
T ₁₆ - Miraculan (2.0 ml/l)	52.5	141.4	176.8	194.8
T ₁₇ - Cytosyme (2.0 ml/l)	52.3	138.3	172.9	188.9
T ₁₈ - APSA (1.0 ml/l)	55.6	133.4	166.8	176.4
T ₁₉ - APSA (2.0 ml/l)	55.8	134.7	168.3	177.8
T ₂₀ - Control	53.2	124.1	155.1	174.0
Mean	54.5	132.8	166.1	184.2
SEm±	0.40	2.28	3.09	3.32
CD (5%)	1.16	6.58	8.94	9.61

APSA = All Purpose Spray Adjuvant

Table 4. Effect of seed hardening and agrochemicals on plant height (cm) at different stages in pigeonpea (2005-06)

Treatment	Days after sowing			
	45	90	120	At harvest
T ₁ - CaCl ₂ (2%)	68.9	166.5	182.3	205.4
T ₂ - MgSO ₄ (100 ppm)	66.5	153.2	180.2	203.3
T ₃ - ZnSO ₄ (100 ppm)	66.2	153.5	180.6	203.7
T ₄ - KH ₂ PO ₄ (1%)	66.9	154.1	181.6	208.0
T ₅ - CCC (100 ppm)	67.0	155.5	183.2	208.7
T ₆ - KCl (100 ppm)	68.2	150.5	176.6	207.4
T ₇ - Ascorbic acid (20 ppm)	66.1	148.0	173.0	210.2
T ₈ - Cobalt nitrate (1000 ppm)	65.8	146.8	171.6	209.0
T ₉ - Sodium molybdate (100 ppm)	67.5	145.6	170.2	210.8
T ₁₀ - Mixtalol (10 ppm)	67.6	154.9	182.3	212.4
T ₁₁ – MgSO ₄ (0.5%)	64.5	154.6	179.5	215.5
T ₁₂ - CCC (500 ppm)	60.0	142.5	176.9	202.0
T ₁₃ - NAA (20 ppm)	64.3	166.0	194.8	218.6
T ₁₄ - NAA (40 ppm)	65.7	167.2	196.6	221.7
T ₁₅ - Triacontanol (20 ppm)	66.0	164.1	192.5	215.8
T ₁₆ - Miraculan (2.0 ml/l)	63.8	165.6	194.5	223.1
T ₁₇ - Cytozyme (2.0 ml/l)	63.2	162.6	190.2	217.5
T ₁₈ - APSA (1.0 ml/l)	66.4	157.5	183.5	204.7
T ₁₉ - APSA (2.0 ml/l)	66.8	158.8	185.2	205.9
T ₂₀ - Control	64.2	148.0	170.6	202.3
Mean	66.0	156.6	182.7	211.0
SEm±	0.36	0.91	1.35	0.73
CD (5%)	1.06	2.62	3.91	2.12

APSA = All Purpose Spray Adjuvant

Table 5. Effect of seed hardening and agrochemicals on plant spread (cm²) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing	
	90 DAS	At harvest
T ₁ - CaCl ₂ (2%)	3515	3126
T ₂ - MgSO ₄ (100 ppm)	3379	2930
T ₃ - ZnSO ₄ (100 ppm)	3399	2861
T ₄ - KH ₂ PO ₄ (1%)	3502	3144
T ₅ - CCC (100 ppm)	3650	3153
T ₆ - KCl (100 ppm)	3475	3031
T ₇ - Ascorbic acid (20 ppm)	3577	3062
T ₈ - Cobalt nitrate (1000 ppm)	3490	3043
T ₉ - Sodium molybdate (100 ppm)	3585	2874
T ₁₀ - Mixtalol (10 ppm)	3623	3169
T ₁₁ - MgSO ₄ (0.5%)	3667	3154
T ₁₂ - CCC (500 ppm)	3689	3161
T ₁₃ - NAA (20 ppm)	3750	3371
T ₁₄ - NAA (40 ppm)	3777	3443
T ₁₅ - Triaccontanol (20 ppm)	3659	3339
T ₁₆ - Miraculan (2.0 ml/l)	3783	3574
T ₁₇ - Cytozyme (2.0 ml/l)	3683	3352
T ₁₈ - APSA (1.0 ml/l)	3348	2841
T ₁₉ - APSA (2.0 ml/l)	3395	2859
T ₂₀ - Control	3156	2657
Mean	3555	3107
SEm±	33.94	38.42
CD (5%)	98.08	111.03

APSA = All Purpose Spray Adjuvant

Table 6. Effect of seed hardening and agrochemicals on plant spread (cm²) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing	
	90 DAS	At harvest
T ₁ - CaCl ₂ (2%)	3794	3257
T ₂ - MgSO ₄ (100 ppm)	3638	3044
T ₃ - ZnSO ₄ (100 ppm)	3660	2968
T ₄ - KH ₂ PO ₄ (1%)	3778	3273
T ₅ - CCC (100 ppm)	3943	3285
T ₆ - KCl (100 ppm)	3748	3153
T ₇ - Ascorbic acid (20 ppm)	3863	3185
T ₈ - Cobalt nitrate (1000 ppm)	3764	3166
T ₉ - Sodium molybdate (100 ppm)	3875	2982
T ₁₀ - Mixtalol (10 ppm)	3915	3299
T ₁₁ - MgSO ₄ (0.5%)	3966	3285
T ₁₂ - CCC (500 ppm)	3988	3294
T ₁₃ - NAA (20 ppm)	4058	3519
T ₁₄ - NAA (40 ppm)	4088	3600
T ₁₅ - Triacantanol (20 ppm)	3957	3485
T ₁₆ - Miraculan (2.0 ml/l)	4098	3740
T ₁₇ - Cytozyme (2.0 ml/l)	3980	3501
T ₁₈ - APSA (1.0 ml/l)	3603	2946
T ₁₉ - APSA (2.0 ml/l)	3657	2967
T ₂₀ - Control	3390	2749
Mean	3838	3235
SEm±	38.69	34.12
CD (5%)	111.80	98.60

APSA = All Purpose Spray Adjuvant

Table 7. Effect of seed hardening and agrochemicals on flower and pod initiation in pigeonpea (2004-05)

Treatment	Flower initiation (days)	Pod initiation (days)
T ₁ - CaCl ₂ (2%)	77.2	115
T ₂ - MgSO ₄ (100 ppm)	79.2	120
T ₃ - ZnSO ₄ (100 ppm)	78.2	121
T ₄ - KH ₂ PO ₄ (1%)	80.3	118
T ₅ - CCC (100 ppm)	80.3	119
T ₆ - KCl (100 ppm)	81.3	122
T ₇ - Ascorbic acid (20 ppm)	79.2	121
T ₈ - Cobalt nitrate (1000 ppm)	80.3	124
T ₉ - Sodium molybdate (100 ppm)	82.3	118
T ₁₀ - Mixtalol (10 ppm)	83.3	117
T ₁₁ - MgSO ₄ (0.5%)	84.3	116
T ₁₂ - CCC (500 ppm)	84.8	118
T ₁₃ - NAA (20 ppm)	85.3	116
T ₁₄ - NAA (40 ppm)	86.9	117
T ₁₅ - Triacntanol (20 ppm)	85.3	117
T ₁₆ - Miraculan (2.0 ml/l)	84.3	118
T ₁₇ - Cytozyme (2.0 ml/l)	86.4	120
T ₁₈ - APSA (1.0 ml/l)	84.3	123
T ₁₉ - APSA (2.0 ml/l)	85.3	118
T ₂₀ - Control	86.4	122
Mean	82.7	119
SEm±	1.05	0.37
CD (5%)	3.04	1.06

APSA = All Purpose Spray Adjuvant

Table 8. Effect of seed hardening and agrochemicals on flower and pod initiation in pigeonpea (2005-06)

Treatment	Flower initiation (days)	Pod initiation (days)
T ₁ - CaCl ₂ (2%)	80.7	122
T ₂ - MgSO ₄ (100 ppm)	82.8	127
T ₃ - ZnSO ₄ (100 ppm)	81.7	129
T ₄ - KH ₂ PO ₄ (1%)	83.9	125
T ₅ - CCC (100 ppm)	82.8	127
T ₆ - KCl (100 ppm)	85.0	129
T ₇ - Ascorbic acid (20 ppm)	82.8	128
T ₈ - Cobalt nitrate (1000 ppm)	83.9	131
T ₉ - Sodium molybdate (100 ppm)	86.0	126
T ₁₀ - Mixtalol (10 ppm)	87.1	124
T ₁₁ - MgSO ₄ (0.5%)	88.2	123
T ₁₂ - CCC (500 ppm)	89.3	125
T ₁₃ - NAA (20 ppm)	88.2	122
T ₁₄ - NAA (40 ppm)	89.3	124
T ₁₅ - Triacantanol (20 ppm)	89.3	122
T ₁₆ - Miraculan (2.0 ml/l)	87.1	124
T ₁₇ - Cytozyme (2.0 ml/l)	89.3	126
T ₁₈ - APSA (1.0 ml/l)	88.2	128
T ₁₉ - APSA (2.0 ml/l)	89.3	125
T ₂₀ - Control	90.3	129
Mean	86.2	126
SEm±	0.98	0.35
CD (5%)	2.86	1.01

APSA = All Purpose Spray Adjuvant

ml/l). However, the number of days to flower initiation was significantly more in control during both the years.

4.1.4 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 during both the years (Table 7 and 8). The plant growth regulators recorded lesser days to pod initiation compared to seed hardening chemicals.

During first year (2004-05), the treatment with CaCl_2 (2 %) recorded less number of days to pod initiation followed by NAA (20 ppm), KH_2PO_4 (1 %), triacontanol (20 ppm), miraculan (2.0 ml/l) and CCC (100 ppm). However, more number of days to pod initiation was recorded in control.

Similarly during second year (2005-06), the treatment T_1 (2.0 per cent CaCl_2) registered lesser number of days to pod initiation followed by NAA (20 ppm), triacontanol (20 ppm), MgSO_4 (0.5%) and NAA (40 ppm). More number of days to pod initiation was recorded in control.

4.1.5 Leaf dry weight (g plant-1)

The data on leaf dry weight as influenced by plant growth regulators and agrochemicals showed significant differences between the treatments at all the stages during both the years. (Table 9 and 10). In general, the leaf dry weight increased from 45 to 120 DAS and decreased thereafter at harvest in all the treatments.

During 2004-05, the treatment with miraculan (2.0 ml/l) recorded significantly higher leaf dry weight over all other treatments at all the stages. However, it was on par with NAA (40 ppm), NAA (20 ppm), triacontanol (20 ppm) and cytozyme (2.0 ml/l) at 45 DAS and 90 DAS. Significantly lower values were recorded in control at all the stages. However, it did not differ significantly with NAA (40 ppm) at 120 DAS and at harvest. A maximum leaf dry weight (21.79 g per plant) was recorded in miraculan (2.0 ml/l) at 120 DAS.

Similarly during 2005-06, the treatment with miraculan (2.0 ml/l) registered higher leaf dry weight at all the stages. However, it was on par with NAA (40 ppm), NAA (20 ppm), triacontanol (20 ppm) and cytozyme (2.0 ml/l) at 45 and 90 DAS. Significant differences were obtained between the treatments at 120 DAS. However, it did not differ significantly with NAA (40 ppm) at harvest. The lowest leaf dry weight was recorded in control. A maximum leaf dry weight of 26.37 g per plant was recorded in miraculan (2.0 ml/l) at 120 DAS.

4.1.6 Total dry weight (g plant-1)

The data on total dry weight revealed significant differences due to the application of plant growth regulators and agrochemicals at all the stages during both the years (Table 11 and 12). The total dry weight increased continuously from 45 DAS to harvest in all the treatments and the increase was almost 10 folds between 45 and 90 DAS during both the years.

During first year (2004-05), the treatment miraculan (2.0 ml/l) registered higher values of total dry matter over all other treatments at all the stages, but it was on par with NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) in all the stages. However, there was no significant differences between the treatments at 45 DAS. Among seed hardening treatments, CaCl_2 (2 %) recorded higher value followed by CCC (100 ppm) and MgSO_4 (100 ppm). Significantly lower dry weight was noticed in control.

Table 9. Effect of seed hardening and agrochemicals on leaf dry weight (g/plant) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	3.15	17.96	19.62	8.78
T ₂ - MgSO ₄ (100 ppm)	3.10	17.70	19.33	8.65
T ₃ - ZnSO ₄ (100 ppm)	3.07	17.50	19.12	8.56
T ₄ - KH ₂ PO ₄ (1%)	3.04	17.30	18.90	8.46
T ₅ - CCC (100 ppm)	3.12	17.79	19.43	8.69
T ₆ - KCl (100 ppm)	3.04	17.33	18.93	8.47
T ₇ - Ascorbic acid (20 ppm)	3.14	17.89	19.55	8.75
T ₈ - Cobalt nitrate (1000 ppm)	3.06	17.46	19.07	8.53
T ₉ - Sodium molybdate (100 ppm)	3.04	17.35	18.95	8.48
T ₁₀ - Mixtalol (10 ppm)	3.08	17.54	19.17	8.58
T ₁₁ - MgSO ₄ (0.5%)	3.24	18.48	20.19	9.04
T ₁₂ - CCC (500 ppm)	3.27	18.66	20.38	9.12
T ₁₃ - NAA (20 ppm)	3.44	19.62	21.43	9.59
T ₁₄ - NAA (40 ppm)	3.48	19.82	21.65	9.69
T ₁₅ - Triacantanol (20 ppm)	3.40	19.38	21.17	9.47
T ₁₆ - Miraculan (2.0 ml/l)	3.50	19.95	21.79	9.75
T ₁₇ - Cytozyme (2.0 ml/l)	3.43	19.53	21.34	9.55
T ₁₈ - APSA (1.0 ml/l)	3.02	17.20	18.78	8.41
T ₁₉ - APSA (2.0 ml/l)	3.05	17.37	18.98	8.49
T ₂₀ - Control	2.85	16.28	17.78	7.96
Mean	3.18	18.10	19.77	8.85
SEm±	0.052	0.37	0.055	0.035
CD (5%)	0.15	1.06	0.16	0.10

APSA = All Purpose Spray Adjuvant

Table 10. Effect of seed hardening and agrochemicals on leaf dry weight (g/plant) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	3.94	21.55	23.74	11.41
T ₂ - MgSO ₄ (100 ppm)	3.88	21.24	23.39	11.25
T ₃ - ZnSO ₄ (100 ppm)	3.84	21.00	23.14	11.13
T ₄ - KH ₂ PO ₄ (1%)	3.80	20.76	22.87	11.00
T ₅ - CCC (100 ppm)	3.90	21.35	23.51	11.30
T ₆ - KCl (100 ppm)	3.80	20.80	22.91	11.01
T ₇ - Ascorbic acid (20 ppm)	3.93	21.47	23.66	11.38
T ₈ - Cobalt nitrate (1000 ppm)	3.83	20.95	23.07	11.09
T ₉ - Sodium molybdate (100 ppm)	3.80	20.82	22.93	11.02
T ₁₀ - Mixtalol (10 ppm)	3.85	21.05	23.20	11.15
T ₁₁ – MgSO ₄ (0.5%)	4.05	22.18	24.43	11.75
T ₁₂ - CCC (500 ppm)	4.09	22.39	24.66	11.86
T ₁₃ - NAA (20 ppm)	4.30	23.54	25.93	12.47
T ₁₄ - NAA (40 ppm)	4.35	23.78	26.20	12.60
T ₁₅ - Triaccontanol (20 ppm)	4.25	23.26	25.62	12.31
T ₁₆ - Miraculan (2.0 ml/l)	4.38	23.94	26.37	12.68
T ₁₇ - Cytozyme (2.0 ml/l)	4.29	23.44	25.82	12.42
T ₁₈ - APSA (1.0 ml/l)	3.78	20.64	22.72	10.93
T ₁₉ - APSA (2.0 ml/l)	3.81	20.84	22.97	11.04
T ₂₀ - Control	3.56	19.54	21.51	10.35
Mean	3.97	21.73	23.93	11.51
SEm±	0.05	0.39	0.04	0.03
CD (5%)	0.14	1.12	0.12	0.10

APSA = All Purpose Spray Adjuvant

Table 11. Effect of seed hardening and agrochemicals on total dry weight (g/plant) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	6.9	72.8	170.7	204.9
T ₂ - MgSO ₄ (100 ppm)	6.8	71.7	168.2	201.9
T ₃ - ZnSO ₄ (100 ppm)	6.7	70.9	166.3	199.6
T ₄ - KH ₂ PO ₄ (1%)	6.6	70.1	164.4	197.4
T ₅ - CCC (100 ppm)	6.8	72.0	169.0	202.9
T ₆ - KCl (100 ppm)	6.6	70.2	164.7	197.6
T ₇ - Ascorbic acid (20 ppm)	6.8	72.5	170.1	204.1
T ₈ - Cobalt nitrate (1000 ppm)	6.7	70.7	165.9	199.1
T ₉ - Sodium molybdate (100 ppm)	6.6	70.3	164.9	197.9
T ₁₀ - Mixtalol (10 ppm)	6.7	71.1	166.7	200.1
T ₁₁ - MgSO ₄ (0.5%)	7.1	74.9	175.7	210.9
T ₁₂ - CCC (500 ppm)	7.1	75.6	177.3	212.9
T ₁₃ - NAA (20 ppm)	7.5	79.5	186.5	223.8
T ₁₄ - NAA (40 ppm)	7.6	80.3	188.3	226.1
T ₁₅ - Triacantanol (20 ppm)	7.4	78.5	184.2	221.1
T ₁₆ - Miraculan (2.0 ml/l)	7.6	80.8	189.6	227.6
T ₁₇ - Cytozyme (2.0 ml/l)	7.5	79.1	185.6	222.8
T ₁₈ - APSA (1.0 ml/l)	6.6	69.7	163.4	196.2
T ₁₉ - APSA (2.0 ml/l)	6.6	70.4	165.1	198.1
T ₂₀ - Control	6.2	65.9	154.7	185.7
Mean	6.9	73.3	172.1	206.5
SEm±	0.22	1.79	2.57	2.79
CD (5%)	0.65	5.16	7.44	8.06

APSA = All Purpose Spray Adjuvant

Table 12. Effect of seed hardening and agrochemicals on total dry weight (g/plant) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	9.66	105.56	230.45	256.13
T ₂ - MgSO ₄ (100 ppm)	9.52	103.97	227.07	252.38
T ₃ - ZnSO ₄ (100 ppm)	9.38	102.81	224.51	249.50
T ₄ - KH ₂ PO ₄ (1%)	9.24	101.65	221.94	246.75
T ₅ - CCC (100 ppm)	9.52	104.40	228.15	253.63
T ₆ - KCl (100 ppm)	9.24	101.79	222.35	247.00
T ₇ - Ascorbic acid (20 ppm)	9.52	105.13	229.64	255.13
T ₈ - Cobalt nitrate (1000 ppm)	9.38	102.52	223.97	248.88
T ₉ - Sodium molybdate (100 ppm)	9.24	101.94	222.62	247.38
T ₁₀ - Mixtalol (10 ppm)	9.38	103.10	225.05	250.13
T ₁₁ - MgSO ₄ (0.5%)	9.94	108.61	237.20	263.63
T ₁₂ - CCC (500 ppm)	9.94	109.62	239.36	266.13
T ₁₃ - NAA (20 ppm)	10.5	115.28	251.78	279.75
T ₁₄ - NAA (40 ppm)	10.64	116.44	254.21	282.63
T ₁₅ - Triacantanol (20 ppm)	10.36	113.83	248.67	276.38
T ₁₆ - Miraculan (2.0 ml/l)	10.64	117.16	255.96	284.50
T ₁₇ - Cytozyme (2.0 ml/l)	10.5	114.70	250.56	278.50
T ₁₈ - APSA (1.0 ml/l)	9.24	101.07	220.59	245.25
T ₁₉ - APSA (2.0 ml/l)	9.24	102.08	222.89	247.63
T ₂₀ - Control	8.68	95.56	208.85	232.13
Mean	9.69	106.36	232.29	258.17
SEm±	0.25	2.13	2.78	3.16
CD (5%)	0.72	6.16	8.04	9.12

APSA = All Purpose Spray Adjuvant

During second season (2005-06), a similar trend was observed with miraculan (2.0 ml/l) recording higher total dry weight over all other treatments at all the stages followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) but it was on par with each other. There were no significant differences among the treatments at 45 DAS. Among the seed hardening chemicals, CaCl_2 (2 %) obtained higher total dry weight followed by ascorbic acid (20 ppm), CCC (100 ppm), MgSO_4 (100 ppm) and ZnSO_4 (100 ppm) at all the stages. However, lesser values were obtained in control.

4.2 GROWTH PARAMETERS

4.2.1 Leaf area (dm^2 plant⁻¹)

Leaf area per plant indicated significant differences among the treatments at all the stages during both the years (Table 13 and 14). Leaf area increased from 45 to 90 DAS and decreased thereafter up to harvest. During both the years, leaf area was more due to plant growth regulators compared to seed hardening chemicals at all the stages.

During first year (2004-05), the treatment miraculan (2.0 ml/l) recorded maximum leaf area followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening chemicals, CaCl_2 (2 %) registered higher leaf area followed by ascorbic acid (20 ppm), CCC (100 ppm), and MgSO_4 (100 ppm). The maximum leaf area was obtained in the treatment with miraculan (2.0 ml/l) at 90 DAS. However, the lower leaf area was recorded in control.

A similar trend was noticed during the second year (2005-06). The treatment with miraculan (2.0 ml/l) recorded higher leaf area followed by NAA (40 ppm), triacontanol (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening treatments, CaCl_2 (2 %) registered higher leaf area compared to other treatments. However, the lowest leaf area was observed in control.

4.2.2 Leaf area index (LAI)

The data on leaf area index (LAI) as influenced by plant growth regulators and seed hardening chemicals showed significant increase from 45 to 90 DAS and thereafter decreased at 120 DAS to harvest (Table 15 and 16). During both the years treatment with miraculan (2.0 ml/l) registered higher leaf area index compared to all other treatments.

During 2004-05, the treatment with miraculan (2.0 ml/l) recorded higher leaf area index followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). However, these treatments are on par with each other. Among seed hardening chemicals, CaCl_2 (2 %) recorded higher leaf area index followed by CCC (100 ppm) and MgSO_4 (100 ppm). The lower leaf area index was noticed in control. The maximum LAI was recorded with miraculan (2.0 ml/l) at 90 DAS.

During second year (2005-06), a similar trend was observed and the treatment with miraculan (2.0 ml/l) registered maximum leaf area index followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and miraculan (2.0 ml/l). However, it is on par with NAA (40 ppm) and NAA (20 ppm) at 45 DAS and with NAA (40 ppm), triacontanol (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) at 90, 120 DAS and at harvest. The lower LAI was obtained in control, and the maximum LAI obtained with miraculan (2.0 ml/l) at 90 DAS.

4.2.3 Absolute growth rate (AGR, g day⁻¹)

The data on absolute growth rate (AGR) indicated significant differences among all the treatments during both the year. (Table 17 and 18) In general AGR increased from 45-90 to 90-120 DAS and decreased thereafter.

Table 13. Effect of seed hardening and agrochemicals on leaf area ($\text{dm}^2 \text{ plant}^{-1}$) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	22.01	60.66	49.17	22.17
T ₂ - MgSO ₄ (100 ppm)	20.21	58.46	47.26	21.57
T ₃ - ZnSO ₄ (100 ppm)	19.38	56.64	46.40	20.92
T ₄ - KH ₂ PO ₄ (1%)	17.78	54.43	45.43	20.14
T ₅ - CCC (100 ppm)	20.62	59.13	47.85	21.77
T ₆ - KCl (100 ppm)	18.05	54.82	45.61	20.16
T ₇ - Ascorbic acid (20 ppm)	21.26	60.26	48.75	21.98
T ₈ - Cobalt nitrate (1000 ppm)	19.06	56.11	46.17	20.50
T ₉ - Sodium molybdate (100 ppm)	18.44	55.09	45.66	20.19
T ₁₀ - Mixtalol (10 ppm)	19.74	57.58	46.64	21.13
T ₁₁ - MgSO ₄ (0.5%)	22.99	62.64	50.72	23.00
T ₁₂ - CCC (500 ppm)	23.55	68.86	51.85	23.32
T ₁₃ - NAA (20 ppm)	25.24	75.12	57.76	25.03
T ₁₄ - NAA (40 ppm)	26.55	79.28	60.81	25.43
T ₁₅ - Triacantanol (20 ppm)	24.46	73.13	54.14	24.34
T ₁₆ - Miraculan (2.0 ml/l)	28.69	79.48	61.72	25.65
T ₁₇ - Cytozyme (2.0 ml/l)	24.85	74.54	55.71	24.87
T ₁₈ - APSA (1.0 ml/l)	17.19	53.91	44.92	20.02
T ₁₉ - APSA (2.0 ml/l)	18.72	55.67	45.84	20.26
T ₂₀ - Control	15.76	50.87	42.33	18.90
Mean	21.25	62.33	49.74	22.07
SEm±	0.78	1.71	1.61	1.21
CD (5%)	2.26	4.94	4.65	3.51

APSA = All Purpose Spray Adjuvant

Table 14. Effect of seed hardening and agrochemicals on leaf area ($\text{dm}^2 \text{ plant}^{-1}$) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	25.05	63.31	52.10	27.08
T ₂ - MgSO ₄ (100 ppm)	23.05	60.96	50.08	26.37
T ₃ - ZnSO ₄ (100 ppm)	21.96	59.10	49.18	25.58
T ₄ - KH ₂ PO ₄ (1%)	20.20	56.77	48.14	24.62
T ₅ - CCC (100 ppm)	23.48	61.68	50.71	26.62
T ₆ - KCl (100 ppm)	20.56	57.24	48.34	24.64
T ₇ - Ascorbic acid (20 ppm)	24.14	62.86	51.67	26.87
T ₈ - Cobalt nitrate (1000 ppm)	21.63	58.58	48.91	25.06
T ₉ - Sodium molybdate (100 ppm)	20.94	57.47	48.38	24.66
T ₁₀ - Mixtalol (10 ppm)	22.44	60.01	49.43	25.81
T ₁₁ - MgSO ₄ (0.5%)	26.11	65.38	53.75	28.10
T ₁₂ - CCC (500 ppm)	26.75	71.84	54.95	28.51
T ₁₃ - NAA (20 ppm)	28.74	78.43	61.20	30.60
T ₁₄ - NAA (40 ppm)	30.19	82.71	64.44	31.08
T ₁₅ - Triacantanol (20 ppm)	27.80	76.33	57.38	29.74
T ₁₆ - Miraculan (2.0 ml/l)	32.64	82.94	65.41	31.36
T ₁₇ - Cytozyme (2.0 ml/l)	28.26	77.80	59.03	30.40
T ₁₈ - APSA (1.0 ml/l)	19.53	56.26	47.60	24.46
T ₁₉ - APSA (2.0 ml/l)	21.25	58.08	48.58	24.76
T ₂₀ - Control	17.88	53.10	44.85	23.11
Mean	24.13	65.04	52.71	26.97
SEm±	1.11	1.29	1.43	0.87
CD (5%)	3.21	3.73	4.13	2.51

APSA = All Purpose Spray Adjuvant

Table 15. Effect of seed hardening and agrochemicals on leaf area index (LAI) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	1.22	3.37	2.73	1.23
T ₂ - MgSO ₄ (100 ppm)	1.13	3.25	2.63	1.20
T ₃ - ZnSO ₄ (100 ppm)	1.07	3.15	2.58	1.16
T ₄ - KH ₂ PO ₄ (1%)	0.99	3.02	2.52	1.12
T ₅ - CCC (100 ppm)	1.15	3.28	2.66	1.21
T ₆ - KCl (100 ppm)	1.01	3.05	2.53	1.12
T ₇ - Ascorbic acid (20 ppm)	1.18	3.35	2.71	1.22
T ₈ - Cobalt nitrate (1000 ppm)	1.06	3.12	2.57	1.14
T ₉ - Sodium molybdate (100 ppm)	1.02	3.06	2.54	1.12
T ₁₀ - Mixtalol (10 ppm)	1.10	3.19	2.59	1.17
T ₁₁ - MgSO ₄ (0.5%)	1.28	3.48	2.82	1.28
T ₁₂ - CCC (500 ppm)	1.31	3.83	2.88	1.30
T ₁₃ - NAA (20 ppm)	1.41	4.18	3.21	1.39
T ₁₄ - NAA (40 ppm)	1.48	4.40	3.38	1.41
T ₁₅ - Triacantanol (20 ppm)	1.36	4.06	3.01	1.35
T ₁₆ - Miraculan (2.0 ml/l)	1.59	4.42	3.43	1.43
T ₁₇ - Cytozyme (2.0 ml/l)	1.38	4.14	3.10	1.38
T ₁₈ - APSA (1.0 ml/l)	0.95	3.00	2.50	1.11
T ₁₉ - APSA (2.0 ml/l)	1.04	3.09	2.55	1.13
T ₂₀ - Control	0.87	2.83	2.35	1.05
Mean	1.18	3.46	2.76	1.23
SEm±	0.079	0.235	0.149	0.045
CD (5%)	0.230	0.680	0.430	0.130

APSA = All Purpose Spray Adjuvant

Table 16. Effect of seed hardening and agrochemicals on leaf area index (LAI) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	1.39	3.52	2.89	1.50
T ₂ - MgSO ₄ (100 ppm)	1.28	3.39	2.78	1.46
T ₃ - ZnSO ₄ (100 ppm)	1.22	3.28	2.73	1.42
T ₄ - KH ₂ PO ₄ (1%)	1.12	3.15	2.67	1.37
T ₅ - CCC (100 ppm)	1.30	3.43	2.82	1.48
T ₆ - KCl (100 ppm)	1.14	3.18	2.69	1.37
T ₇ - Ascorbic acid (20 ppm)	1.34	3.49	2.87	1.49
T ₈ - Cobalt nitrate (1000 ppm)	1.20	3.25	2.72	1.39
T ₉ - Sodium molybdate (100 ppm)	1.16	3.19	2.69	1.37
T ₁₀ - Mixtalol (10 ppm)	1.25	3.33	2.75	1.43
T ₁₁ - MgSO ₄ (0.5%)	1.45	3.63	2.99	1.56
T ₁₂ - CCC (500 ppm)	1.49	3.99	3.05	1.58
T ₁₃ - NAA (20 ppm)	1.60	4.36	3.40	1.70
T ₁₄ - NAA (40 ppm)	1.68	4.60	3.58	1.73
T ₁₅ - Triacantanol (20 ppm)	1.54	4.24	3.19	1.65
T ₁₆ - Miraculan (2.0 ml/l)	1.81	4.61	3.63	1.74
T ₁₇ - Cytozyme (2.0 ml/l)	1.57	4.32	3.28	1.69
T ₁₈ - APSA (1.0 ml/l)	1.08	3.13	2.64	1.36
T ₁₉ - APSA (2.0 ml/l)	1.18	3.23	2.70	1.38
T ₂₀ - Control	0.99	2.95	2.49	1.28
Mean	1.34	3.61	2.93	1.50
SEm±	0.07	0.27	0.16	0.05
CD (5%)	0.21	0.79	0.48	0.14

APSA = All Purpose Spray Adjuvant

During first year (2004-05), the treatment with miraculan (2.0 ml/l) recorded higher values of AGR followed by NAA (40 ppm), triacontanol (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). However, these were on par with each other. Among the seed hardening chemicals, CaCl_2 (2 %) and ascorbic acid (20 ppm) registered higher AGR followed by CCC (100 ppm). However the lower AGR was recorded in control.

A similar trend was observed during 2005-06. The treatment with miraculan (2.0 ml/l) registered higher absolute growth rate followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) at all the stages. However, these were on par with each other. Among seed hardening chemicals, the higher absolute growth rate was obtained with the treatment CaCl_2 (2 %) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). The lower value was noticed in control.

4.2.4 Crop growth rate (CGR, $\text{g m}^{-2} \text{ day}^{-1}$)

The data on crop growth presented in Table 19 and 20 indicated significant differences among the treatments at all the stages. It was further observed that the CGR was maximum between 90-120 DAS and declined towards maturity. The same trend was followed during both the year (2004-05 and 2005-06).

During first year (2004-05) the treatment with miraculan (2 ml /l) had higher CGR at all the stages followed by NAA (40ppm), NAA (20ppm), cytozyme (2.0ml /l) and triacontanol (20ppm). Among the seed hardening treatments, CaCl_2 (2 %) had higher CGR at all the stages followed by ascorbic acid (20ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, these treatments were on par with each other.

During second year (2005-06) the same trend was noticed between the treatments at all the stages. The higher CGR was recorded with miraculan (2 ml/l) at 90-120 DAS. Among the plant growth regulators the treatment miraculan (2 ml/l) recorded the higher CGR at all the stages followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening chemicals CaCl_2 (2 %) recorded higher CGR at all the stages followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, these were on par with each other. The lower CGR was recorded in control.

4.2.5. Relative growth rate (RGR, $\text{g g}^{-1} \text{ day}^{-1}$)

The data indicated that the relative growth rate (RGR) exhibited significant differences among the treatments at different stages during both the years (2004-05 and 2005-06). In general it is clear from the data that RGR declined with an increase in the crop growth. RGR was maximum at 45- 90 DAS and thereafter it declined at maturity (Table 21 and 22).

During 2004-05 the treatment with miraculan (2.0 ml/l) registered higher RGR followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) at all stages. Among the seed hardening chemicals, CaCl_2 (2 %) and ascorbic acid (20 ppm) had higher RGR followed by MgSO_4 (100 ppm) and KH_2PO_4 (1 %) at all the stages but they were on par with each other. The higher RGR was recorded in miraculan (2.0 ml/l) at 45-90 DAS.

Similarly during 2005-06, the higher RGR was recorded in the treatment miraculan (2 ml/l) at 45-90 DAS. However, the lower value of RGR was observed in control.

Table 17. Effect of seed hardening and agrochemicals on absolute growth rate (AGR) at different growth stages in pigeonpea (2004-05)

Treatment	AGR (g day ⁻¹)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	1.46	3.26	0.52
T ₂ - MgSO ₄ (100 ppm)	1.44	3.22	0.51
T ₃ - ZnSO ₄ (100 ppm)	1.43	3.18	0.51
T ₄ - KH ₂ PO ₄ (1%)	1.41	3.15	0.50
T ₅ - CCC (100 ppm)	1.45	3.23	0.51
T ₆ - KCl (100 ppm)	1.41	3.15	0.50
T ₇ - Ascorbic acid (20 ppm)	1.46	3.25	0.52
T ₈ - Cobalt nitrate (1000 ppm)	1.42	3.17	0.50
T ₉ - Sodium molybdate (100 ppm)	1.41	3.15	0.50
T ₁₀ - Mixtalol (10 ppm)	1.43	3.19	0.51
T ₁₁ – MgSO ₄ (0.5%)	1.51	3.36	0.53
T ₁₂ - CCC (500 ppm)	1.52	3.39	0.54
T ₁₃ - NAA (20 ppm)	1.60	3.57	0.57
T ₁₄ - NAA (40 ppm)	1.62	3.60	0.57
T ₁₅ - Triacantanol (20 ppm)	1.58	3.52	0.56
T ₁₆ - Miraculan (2.0 ml/l)	1.63	3.63	0.58
T ₁₇ - Cytozyme (2.0 ml/l)	1.59	3.55	0.56
T ₁₈ - APSA (1.0 ml/l)	1.40	3.13	0.50
T ₁₉ - APSA (2.0 ml/l)	1.42	3.16	0.50
T ₂₀ - Control	1.33	2.96	0.47
Mean	1.48	3.29	0.52
SEm±	0.062	0.076	0.035
CD (5%)	0.180	0.220	0.100

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 18. Effect of seed hardening and agrochemicals on absolute growth rate (AGR) at different growth stages in pigeonpea (2005-06)

Treatment	AGR (g day ⁻¹)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	2.13	4.16	0.43
T ₂ - MgSO ₄ (100 ppm)	2.10	4.10	0.42
T ₃ - ZnSO ₄ (100 ppm)	2.08	4.06	0.42
T ₄ - KH ₂ PO ₄ (1%)	2.05	4.01	0.41
T ₅ - CCC (100 ppm)	2.11	4.13	0.42
T ₆ - KCl (100 ppm)	2.06	4.02	0.41
T ₇ - Ascorbic acid (20 ppm)	2.12	4.15	0.42
T ₈ - Cobalt nitrate (1000 ppm)	2.07	4.05	0.42
T ₉ - Sodium molybdate (100 ppm)	2.06	4.02	0.41
T ₁₀ - Mixtalol (10 ppm)	2.08	4.07	0.42
T ₁₁ - MgSO ₄ (0.5%)	2.19	4.29	0.44
T ₁₂ - CCC (500 ppm)	2.22	4.32	0.45
T ₁₃ - NAA (20 ppm)	2.33	4.55	0.47
T ₁₄ - NAA (40 ppm)	2.35	4.59	0.47
T ₁₅ - Triacantanol (20 ppm)	2.30	4.49	0.46
T ₁₆ - Miraculan (2.0 ml/l)	2.37	4.63	0.48
T ₁₇ - Cytozyme (2.0 ml/l)	2.32	4.53	0.47
T ₁₈ - APSA (1.0 ml/l)	2.04	3.98	0.41
T ₁₉ - APSA (2.0 ml/l)	2.06	4.03	0.41
T ₂₀ - Control	1.93	3.78	0.39
Mean	2.15	4.20	0.43
SEm±	0.05	0.10	0.03
CD (5%)	0.16	0.28	0.11

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 19. Effect of seed hardening and agrochemicals on crop growth rate (CGR) at different growth stages in pigeonpea (2004-05)

Treatment	CGR (g m ⁻² day ⁻¹)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	8.13	18.12	2.88
T ₂ - MgSO ₄ (100 ppm)	8.01	17.85	2.83
T ₃ - ZnSO ₄ (100 ppm)	7.92	17.65	2.80
T ₄ - KH ₂ PO ₄ (1%)	7.83	17.45	2.77
T ₅ - CCC (100 ppm)	8.05	17.94	2.85
T ₆ - KCl (100 ppm)	7.84	17.48	2.77
T ₇ - Ascorbic acid (20 ppm)	8.10	18.05	2.86
T ₈ - Cobalt nitrate (1000 ppm)	7.90	17.61	2.80
T ₉ - Sodium molybdate (100 ppm)	7.85	17.50	2.78
T ₁₀ - Mixtalol (10 ppm)	7.94	17.70	2.81
T ₁₁ – MgSO ₄ (0.5%)	8.36	18.64	2.96
T ₁₂ - CCC (500 ppm)	8.44	18.82	2.99
T ₁₃ - NAA (20 ppm)	8.88	19.79	3.14
T ₁₄ - NAA (40 ppm)	8.97	19.99	3.17
T ₁₅ - Triacantanol (20 ppm)	8.77	19.55	3.10
T ₁₆ - Miraculan (2.0 ml/l)	9.03	20.12	3.19
T ₁₇ - Cytozyme (2.0 ml/l)	8.84	19.70	3.13
T ₁₈ - APSA (1.0 ml/l)	7.78	17.34	2.75
T ₁₉ - APSA (2.0 ml/l)	7.86	17.52	2.78
T ₂₀ - Control	7.37	16.42	2.61
Mean	8.19	18.26	2.90
SEm±	0.284	0.429	0.076
CD (5%)	0.820	1.240	0.220

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 20. Effect of seed hardening and agrochemicals on crop growth rate (CGR) at different growth stages in pigeonpea (2005-06)

Treatment	CGR (g m ⁻² day ⁻¹)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	11.83	23.10	2.38
T ₂ - MgSO ₄ (100 ppm)	11.65	22.77	2.34
T ₃ - ZnSO ₄ (100 ppm)	11.52	22.51	2.31
T ₄ - KH ₂ PO ₄ (1%)	11.40	22.25	2.29
T ₅ - CCC (100 ppm)	11.70	22.89	2.36
T ₆ - KCl (100 ppm)	11.41	22.30	2.28
T ₇ - Ascorbic acid (20 ppm)	11.79	23.03	2.36
T ₈ - Cobalt nitrate (1000 ppm)	11.49	22.47	2.30
T ₉ - Sodium molybdate (100 ppm)	11.43	22.33	2.29
T ₁₀ - Mixtalol (10 ppm)	11.56	22.56	2.32
T ₁₁ – MgSO ₄ (0.5%)	12.17	23.79	2.44
T ₁₂ - CCC (500 ppm)	12.29	24.00	2.48
T ₁₃ - NAA (20 ppm)	12.92	25.25	2.59
T ₁₄ - NAA (40 ppm)	13.05	25.49	2.63
T ₁₅ - Triacntanol (20 ppm)	12.76	24.95	2.56
T ₁₆ - Miraculan (2.0 ml/l)	13.14	25.68	2.64
T ₁₇ - Cytozyme (2.0 ml/l)	12.85	25.13	2.58
T ₁₈ - APSA (1.0 ml/l)	11.33	22.11	2.28
T ₁₉ - APSA (2.0 ml/l)	11.45	22.35	2.29
T ₂₀ - Control	10.72	20.96	2.15
Mean	11.92	23.30	2.39
SEm±	0.31	0.40	0.08
CD (5%)	0.89	1.16	0.24

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 21. Effect of seed hardening and agrochemicals on relative growth rate (RGR) at different growth stages in pigeonpea (2004-05)

Treatment	RGR (g g ⁻¹ day ⁻¹)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	0.0526	0.0278	0.0023
T ₂ - MgSO ₄ (100 ppm)	0.0524	0.0262	0.0021
T ₃ - ZnSO ₄ (100 ppm)	0.0523	0.0258	0.002
T ₄ - KH ₂ PO ₄ (1%)	0.0524	0.0244	0.0014
T ₅ - CCC (100 ppm)	0.0522	0.027	0.0022
T ₆ - KCl (100 ppm)	0.0521	0.0248	0.0016
T ₇ - Ascorbic acid (20 ppm)	0.0526	0.0272	0.0022
T ₈ - Cobalt nitrate (1000 ppm)	0.0522	0.0256	0.0019
T ₉ - Sodium molybdate (100 ppm)	0.0523	0.025	0.0018
T ₁₀ - Mixtalol (10 ppm)	0.0523	0.026	0.002
T ₁₁ – MgSO ₄ (0.5%)	0.0527	0.0279	0.0024
T ₁₂ - CCC (500 ppm)	0.0528	0.025	0.0027
T ₁₃ - NAA (20 ppm)	0.053	0.0284	0.0032
T ₁₄ - NAA (40 ppm)	0.0531	0.0288	0.0034
T ₁₅ - Triacantanol (20 ppm)	0.0529	0.028	0.0029
T ₁₆ - Miraculan (2.0 ml/l)	0.0533	0.0291	0.0039
T ₁₇ - Cytoszyme (2.0 ml/l)	0.053	0.0282	0.003
T ₁₈ - APSA (1.0 ml/l)	0.0525	0.0242	0.0013
T ₁₉ - APSA (2.0 ml/l)	0.0525	0.0253	0.0018
T ₂₀ - Control	0.0512	0.0241	0.0012
Mean	0.0525	0.0264	0.0023
SEm±	0.0042	0.0007	0.0007
CD (5%)	0.0120	0.0020	0.0020

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 22. Effect of seed hardening and agrochemicals on relative growth rate (RGR) at different growth stages in pigeonpea (2005-06)

Treatment	RGR (g g ⁻¹ day ⁻¹)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	0.0538	0.0267	0.0030
T ₂ - MgSO ₄ (100 ppm)	0.0531	0.0261	0.0025
T ₃ - ZnSO ₄ (100 ppm)	0.0532	0.0260	0.0020
T ₄ - KH ₂ PO ₄ (1%)	0.0533	0.0263	0.0026
T ₅ - CCC (100 ppm)	0.0534	0.0261	0.0018
T ₆ - KCl (100 ppm)	0.0533	0.0260	0.0018
T ₇ - Ascorbic acid (20 ppm)	0.0537	0.0265	0.0028
T ₈ - Cobalt nitrate (1000 ppm)	0.0531	0.0261	0.0025
T ₉ - Sodium molybdate (100 ppm)	0.0534	0.0263	0.0018
T ₁₀ - Mixtalol (10 ppm)	0.0533	0.0260	0.0023
T ₁₁ – MgSO ₄ (0.5%)	0.0538	0.0270	0.0022
T ₁₂ - CCC (500 ppm)	0.0540	0.0273	0.0031
T ₁₃ - NAA (20 ppm)	0.0549	0.0275	0.0035
T ₁₄ - NAA (40 ppm)	0.0547	0.0278	0.0037
T ₁₅ - Triacntanol (20 ppm)	0.0544	0.0272	0.0033
T ₁₆ - Miraculan (2.0 ml/l)	0.0552	0.0281	0.0039
T ₁₇ - Cytozyme (2.0 ml/l)	0.0545	0.0275	0.0035
T ₁₈ - APSA (1.0 ml/l)	0.0532	0.0261	0.0021
T ₁₉ - APSA (2.0 ml/l)	0.0534	0.02603	0.0018
T ₂₀ - Control	0.0530	0.0258	0.0014
Mean	0.0537	0.0266	0.0026
SEm±	0.0038	0.0003	0.0003
CD (5%)	0.0110	0.0010	0.0010

APSA = All Purpose Spray Adjuvant
DAS: Days after sowin

4.2.6 Net assimilation rate (NAR, $\text{mg dm}^{-2} \text{ day}^{-1}$)

The data on net assimilation rate (NAR) indicated significant differences among the treatments at all the stages during both the years (Table 23 and 24). It was also observed that NAR was maximum at 90-120 DAS and thereafter declined with the age of the crop.

During 2004-05 the treatment with miraculan (2 ml/l) registered maximum NAR followed by NAA (40 ppm), NAA (20 ppm) and APSA (1.0 ml/l). However, these were on par with each other. Among seed hardening chemicals, KCl (100 ppm) recorded higher NAR followed by ascorbic acid (20 ppm) and sodium molybdate (100 ppm).

The same trend was observed during 2005-06 in both plant growth regulators as well as seed hardening treatments. The maximum NAR was recorded with miraculan (2.0 ml/l). However the lower NAR was observed in control.

4.2.7 Specific leaf weight (SLW, mg cm^{-2})

The data on specific leaf weight as influenced by plant growth regulators and agrochemicals indicated significant differences between the treatments at all the stages during both the years (Table 25 and 26). In general the SLW increased as the age of the crop advanced.

During first year (2004-05), specific leaf weight increased from 45 DAS to 120 DAS in all the treatments. Among the plant growth regulators, treatment with miraculan (2.0 ml/l) registered higher SLW followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). However, these were on par with each other. Among the seed hardening chemicals, CaCl_2 (2 %), and ascorbic acid (20 ppm) had higher SLW followed by MgSO_4 (100 ppm) and KH_2PO_4 (1 %) at all the stages but they were on par with each other.

Similarly, during 2005-06 SLW increased from 45 DAS to 120 DAS in all the treatments. The higher SLW was recorded in the treatment with miraculan (2 ml/l) followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). However, these were on par with each other. With respect to seed hardening chemicals, the same trend was observed and the treatment with CaCl_2 (2 %) and ascorbic acid (20 ppm) had higher SLW followed by MgSO_4 (100 ppm) and KH_2PO_4 (1 %) at all the stages. The lower SLW was recorded in control.

4.2.8 Specific leaf area (SLA, $\text{cm}^2 \text{ mg}^{-1}$)

It was noticed from the Table 27 and 28 that, specific leaf area (SLA) as influenced by plant growth regulators and agrochemicals indicated significant differences among the treatments at all the stages during both the years (2004-05 and 2005-06). In general specific leaf area decreased as the age of the crop advanced. SLA is maximum at 45 DAS and decreased thereafter towards harvest.

During 2004-05 the treatment with miraculan (2.0 ml/l) registered maximum SLA followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) except at 90 DAS. And at 90 DAS the treatment with MgSO_4 (100 ppm) recorded higher SLA followed by miraculan (2.0 ml/l), NAA (20 ppm) and cytozyme (2.0 ml/l). However, these were on par with each other. Among seed hardening chemicals the treatment with MgSO_4 (100 ppm) recorded maximum SLA followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm) at all the stages. The lower SLA is recorded in control.

During 2005-06, the same trend was observed. The treatment with miraculan (2.0 ml/l) recorded maximum SLA with respect to plant growth regulators treatment followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) except at 90 DAS. Treatment with NAA (40 ppm) recorded higher SLA at 90 DAS followed by miraculan

Table 23. Effect of seed hardening and agrochemicals on net assimilation rate (NAR) at different growth stages in pigeonpea (2004-05)

Treatment	NAR (mg dm ⁻² day ⁻¹)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	0.400	0.600	0.500
T ₂ - MgSO ₄ (100 ppm)	0.300	0.700	0.400
T ₃ - ZnSO ₄ (100 ppm)	0.400	0.500	0.200
T ₄ - KH ₂ PO ₄ (1%)	0.500	0.700	0.200
T ₅ - CCC (100 ppm)	0.400	0.500	0.500
T ₆ - KCl (100 ppm)	0.600	0.600	0.400
T ₇ - Ascorbic acid (20 ppm)	0.500	0.800	0.300
T ₈ - Cobalt nitrate (1000 ppm)	0.300	0.600	0.300
T ₉ - Sodium molybdate (100 ppm)	0.500	0.400	0.200
T ₁₀ - Mixtalol (10 ppm)	0.500	0.800	0.200
T ₁₁ – MgSO ₄ (0.5%)	0.500	0.800	0.300
T ₁₂ - CCC (500 ppm)	0.500	0.500	0.400
T ₁₃ - NAA (20 ppm)	0.700	0.800	0.400
T ₁₄ - NAA (40 ppm)	0.700	0.900	0.500
T ₁₅ - Triaccontanol (20 ppm)	0.600	0.700	0.300
T ₁₆ - Miraculan (2.0 ml/l)	0.800	1.200	0.600
T ₁₇ - Cytozyme (2.0 ml/l)	0.600	0.600	0.400
T ₁₈ - APSA (1.0 ml/l)	0.700	0.700	0.200
T ₁₉ - APSA (2.0 ml/l)	0.300	0.300	0.400
T ₂₀ - Control	0.200	0.400	0.100
Mean	0.600	0.700	0.300
SEm±	0.05	0.04	0.03
CD (5%)	0.16	0.12	0.10

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 24. Effect of seed hardening and agrochemicals on net assimilation rate (NAR) at different growth stages in pigeonpea (2005-06)

Treatment	NAR (mg dm ⁻² day ⁻¹)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	1.200	0.900	0.300
T ₂ - MgSO ₄ (100 ppm)	0.800	0.700	0.200
T ₃ - ZnSO ₄ (100 ppm)	0.600	0.600	0.400
T ₄ - KH ₂ PO ₄ (1%)	0.500	0.800	0.300
T ₅ - CCC (100 ppm)	0.700	0.700	0.100
T ₆ - KCl (100 ppm)	0.600	0.600	0.200
T ₇ - Ascorbic acid (20 ppm)	0.800	0.700	0.100
T ₈ - Cobalt nitrate (1000 ppm)	0.700	0.800	0.200
T ₉ - Sodium molybdate (100 ppm)	0.800	0.800	0.100
T ₁₀ - Mixtalol (10 ppm)	0.500	0.700	0.100
T ₁₁ – MgSO ₄ (0.5%)	1.100	0.700	0.300
T ₁₂ - CCC (500 ppm)	0.800	0.800	0.300
T ₁₃ - NAA (20 ppm)	1.000	0.900	0.500
T ₁₄ - NAA (40 ppm)	1.200	0.900	0.500
T ₁₅ - Triacantanol (20 ppm)	0.900	0.800	0.400
T ₁₆ - Miraculan (2.0 ml/l)	1.400	1.000	0.600
T ₁₇ - Cytozyme (2.0 ml/l)	1.000	0.800	0.400
T ₁₈ - APSA (1.0 ml/l)	0.600	0.700	0.400
T ₁₉ - APSA (2.0 ml/l)	0.800	0.800	0.200
T ₂₀ - Control	0.400	0.500	0.100
Mean	0.800	0.700	0.300
SEm±	0.07	0.05	0.05
CD (5%)	0.21	0.14	0.16

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 25. Effect of seed hardening and agrochemicals on specific leaf weight (SLW, mg cm⁻²) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing		
	45	90	120
T ₁ - CaCl ₂ (2%)	1.65	3.18	4.16
T ₂ - MgSO ₄ (100 ppm)	1.53	3.03	4.09
T ₃ - ZnSO ₄ (100 ppm)	1.59	3.09	4.12
T ₄ - KH ₂ PO ₄ (1%)	1.36	2.96	3.99
T ₅ - CCC (100 ppm)	1.61	3.01	4.06
T ₆ - KCl (100 ppm)	1.38	2.61	4.15
T ₇ - Ascorbic acid (20 ppm)	1.48	2.97	4.01
T ₈ - Cobalt nitrate (1000 ppm)	1.51	3.11	4.13
T ₉ - Sodium molybdate (100 ppm)	1.43	2.65	3.71
T ₁₀ - Mixtalol (10 ppm)	1.56	3.05	4.11
T ₁₁ - MgSO ₄ (0.5%)	1.41	2.95	3.91
T ₁₂ - CCC (500 ppm)	1.39	2.71	3.93
T ₁₃ - NAA (20 ppm)	1.71	3.16	4.15
T ₁₄ - NAA (40 ppm)	1.76	3.19	4.18
T ₁₅ - Triacantanol (20 ppm)	1.63	3.15	3.98
T ₁₆ - Miraculan (2.0 ml/l)	1.81	3.20	4.20
T ₁₇ - Cytozyme (2.0 ml/l)	1.68	3.15	4.14
T ₁₈ - APSA (1.0 ml/l)	1.31	2.50	3.56
T ₁₉ - APSA (2.0 ml/l)	1.39	2.62	3.53
T ₂₀ - Control	1.22	2.47	3.50
Mean	1.52	2.94	4.00
SEm±	0.100	0.079	0.093
CD (5%)	0.290	0.230	0.270

APSA = All Purpose Spray Adjuvant

Table 26. Effect of seed hardening and agrochemicals on specific leaf weight (SLW, mg cm⁻²) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing		
	45	90	120
T ₁ - CaCl ₂ (2%)	1.88	3.66	4.75
T ₂ - MgSO ₄ (100 ppm)	1.68	3.48	4.67
T ₃ - ZnSO ₄ (100 ppm)	1.75	3.55	4.71
T ₄ - KH ₂ PO ₄ (1%)	1.57	3.40	4.56
T ₅ - CCC (100 ppm)	1.66	3.46	4.64
T ₆ - KCl (100 ppm)	1.63	3.42	4.58
T ₇ - Ascorbic acid (20 ppm)	1.85	3.63	4.74
T ₈ - Cobalt nitrate (1000 ppm)	1.53	3.05	4.47
T ₉ - Sodium molybdate (100 ppm)	1.50	3.00	4.24
T ₁₀ - Mixtalol (10 ppm)	1.72	3.51	4.69
T ₁₁ - MgSO ₄ (0.5%)	1.55	3.39	4.55
T ₁₂ - CCC (500 ppm)	1.53	3.12	4.49
T ₁₃ - NAA (20 ppm)	1.82	3.62	4.74
T ₁₄ - NAA (40 ppm)	1.94	3.67	4.77
T ₁₅ - Triacantanol (20 ppm)	1.77	3.58	4.72
T ₁₆ - Miraculan (2.0 ml/l)	1.99	3.68	4.80
T ₁₇ - Cytozyme (2.0 ml/l)	1.79	3.59	4.73
T ₁₈ - APSA (1.0 ml/l)	1.44	2.88	4.07
T ₁₉ - APSA (2.0 ml/l)	1.52	3.01	4.37
T ₂₀ - Control	1.34	2.89	4.03
Mean	1.67	3.38	4.56
SEm±	0.09	0.07	0.10
CD (5%)	0.28	0.19	0.29

APSA = All Purpose Spray Adjuvant

Table 27. Effect of seed hardening and agrochemicals on specific leaf area (SLA, cm² mg⁻¹) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	0.699	0.338	0.251	0.253
T ₂ - MgSO ₄ (100 ppm)	0.654	0.330	0.244	0.249
T ₃ - ZnSO ₄ (100 ppm)	0.629	0.324	0.243	0.244
T ₄ - KH ₂ PO ₄ (1%)	0.585	0.314	0.240	0.238
T ₅ - CCC (100 ppm)	0.662	0.332	0.246	0.251
T ₆ - KCl (100 ppm)	0.595	0.316	0.241	0.238
T ₇ - Ascorbic acid (20 ppm)	0.676	0.337	0.249	0.251
T ₈ - Cobalt nitrate (1000 ppm)	0.621	0.322	0.242	0.240
T ₉ - Sodium molybdate (100 ppm)	0.606	0.317	0.241	0.238
T ₁₀ - Mixtalol (10 ppm)	0.641	0.328	0.243	0.246
T ₁₁ - MgSO ₄ (0.5%)	0.709	0.339	0.251	0.254
T ₁₂ - CCC (500 ppm)	0.719	0.369	0.254	0.256
T ₁₃ - NAA (20 ppm)	0.735	0.383	0.270	0.261
T ₁₄ - NAA (40 ppm)	0.763	0.400	0.281	0.262
T ₁₅ - Triacantanol (20 ppm)	0.719	0.377	0.256	0.257
T ₁₆ - Miraculan (2.0 ml/l)	0.820	0.398	0.283	0.263
T ₁₇ - Cytozyme (2.0 ml/l)	0.725	0.382	0.261	0.260
T ₁₈ - APSA (1.0 ml/l)	0.568	0.313	0.239	0.238
T ₁₉ - APSA (2.0 ml/l)	0.613	0.321	0.242	0.239
T ₂₀ - Control	0.552	0.313	0.238	0.238
Mean	0.66	0.34	0.25	0.25
SEm±	0.043	0.021	0.011	0.005
CD (5%)	0.123	0.062	0.032	0.016

APSA = All Purpose Spray Adjuvant

Table 28. Effect of seed hardening and agrochemicals on specific leaf area (SLA, $\text{cm}^2 \text{mg}^{-1}$) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	0.637	0.294	0.219	0.238
T ₂ - MgSO ₄ (100 ppm)	0.595	0.287	0.214	0.234
T ₃ - ZnSO ₄ (100 ppm)	0.571	0.282	0.212	0.230
T ₄ - KH ₂ PO ₄ (1%)	0.532	0.273	0.211	0.224
T ₅ - CCC (100 ppm)	0.602	0.289	0.216	0.235
T ₆ - KCl (100 ppm)	0.541	0.275	0.211	0.224
T ₇ - Ascorbic acid (20 ppm)	0.613	0.292	0.218	0.236
T ₈ - Cobalt nitrate (1000 ppm)	0.565	0.279	0.212	0.226
T ₉ - Sodium molybdate (100 ppm)	0.549	0.276	0.211	0.224
T ₁₀ - Mixtalol (10 ppm)	0.581	0.285	0.213	0.231
T ₁₁ - MgSO ₄ (0.5%)	0.645	0.295	0.220	0.239
T ₁₂ - CCC (500 ppm)	0.654	0.321	0.223	0.240
T ₁₃ - NAA (20 ppm)	0.667	0.333	0.236	0.245
T ₁₄ - NAA (40 ppm)	0.694	0.347	0.246	0.247
T ₁₅ - Triacantanol (20 ppm)	0.654	0.328	0.224	0.242
T ₁₆ - Miraculan (2.0 ml/l)	0.746	0.346	0.248	0.248
T ₁₇ - Cytozyme (2.0 ml/l)	0.658	0.332	0.229	0.244
T ₁₈ - APSA (1.0 ml/l)	0.515	0.272	0.210	0.224
T ₁₉ - APSA (2.0 ml/l)	0.559	0.279	0.211	0.224
T ₂₀ - Control	0.503	0.272	0.208	0.223
Mean	0.604	0.298	0.220	0.234
SEm±	0.038	0.015	0.009	0.005
CD (5%)	0.110	0.043	0.027	0.014

APSA = All Purpose Spray Adjuvant

(2.0 ml/l), NAA (20 ppm) and cytozyme (2.0 ml/l). Among seed hardening chemicals, CaCl_2 (2 %) recorded maximum SLA followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, these were on par with each other. The lower SLA recorded in control.

4.2.9 Leaf area ratio (LAR, $\text{cm}^2 \text{g}^{-1}$)

The data on leaf area ratio (LAR) as influenced by plant growth regulators and agrochemicals showed significant differences among the treatments at all the stages during both the years (Table 29 and 30). In general the LAR was higher in the initial stage and decreased thereafter drastically as the age of crop advanced.

During first year (2004-05), the higher LAR was recorded with the treatment miraculan (2 ml/l) followed by NAA (40ppm), NAA (20ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) except at 90 DAS. Treatment with NAA (40 ppm) recorded higher LAR at 90 DAS followed by miraculan (2.0 ml/l) and NAA (20 ppm). However, these were on par with each other at 120 DAS. Treatment with miraculan (2.0 ml/l) was on par with NAA (40 ppm) and NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among seed hardening chemicals, the treatment CaCl_2 (2 %) registered higher LAR followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm) at all the stages. However, these were on par with each other. The lower LAR was noticed in control. During second year (2005-06) the same trend was observed. The treatment with miraculan (2.0 ml/l) recorded higher LAR except at 90 DAS. The maximum LAR recorded in the treatment miraculan (2.0 ml/l) is 306.75 at 45 DAS. However, the lower value of LAR was recorded in control.

4.2.10 Leaf area duration (LAD, days)

The data on leaf area duration (LAD) as influenced by plant growth regulators and agrochemicals showed significant differences among the treatments at all the stages during both the years (Table 31 and 32).

During first year (2004-05), the treatment with miraculan (2.0 ml/l) registered higher LAD followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). However, these were on par with each other. Among the seed hardening chemicals, CaCl_2 (2 %) and ascorbic acid (20 ppm) had higher LAD followed by MgSO_4 (100 ppm) and KH_2PO_4 (1 %) at all the stages but they were on par with each other.

Similarly during second year (2005-06), the higher LAD was recorded with the treatment miraculan (2.0 ml/l) followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). With respect to seed hardening chemicals, the same trend was observed and the treatment with CaCl_2 (2 %) and ascorbic acid (20 ppm) had higher LAD followed by MgSO_4 (100 ppm) and KH_2PO_4 (1 %) at all the stages. The lower LAD was recorded in control.

4.2.11 Biomass duration (BMD, g days)

The data pertaining to biomass duration (BMD) indicated significant differences among all the treatment at all the stages during both the years (Table 33 and 34). In general BMD increased continuously from 45 DAS to harvest in all the treatments at all the stages during both the years.

Table 29. Effect of seed hardening and agrochemicals on leaf area ratio (LAR, $\text{cm}^2 \text{g}^{-1}$) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	321.4	83.4	28.8	10.8
T ₂ - MgSO ₄ (100 ppm)	300.2	81.5	28.1	10.7
T ₃ - ZnSO ₄ (100 ppm)	289.0	79.9	27.9	10.5
T ₄ - KH ₂ PO ₄ (1%)	269.4	77.6	27.6	10.2
T ₅ - CCC (100 ppm)	304.8	82.0	28.3	10.7
T ₆ - KCl (100 ppm)	273.8	78.1	27.7	10.2
T ₇ - Ascorbic acid (20 ppm)	310.6	83.1	28.7	10.8
T ₈ - Cobalt nitrate (1000 ppm)	285.4	79.4	27.8	10.3
T ₉ - Sodium molybdate (100 ppm)	278.3	78.4	27.7	10.2
T ₁₀ - Mixtalol (10 ppm)	295.1	80.9	28.0	10.6
T ₁₁ - MgSO ₄ (0.5%)	325.9	83.7	28.9	10.9
T ₁₂ - CCC (500 ppm)	330.4	91.1	29.3	11.0
T ₁₃ - NAA (20 ppm)	338.2	94.6	31.0	11.2
T ₁₄ - NAA (40 ppm)	351.4	98.8	32.3	11.3
T ₁₅ - Triacantanol (20 ppm)	331.0	93.2	29.4	11.0
T ₁₆ - Miraculan (2.0 ml/l)	377.0	98.4	32.6	11.3
T ₁₇ - Cytozyme (2.0 ml/l)	333.6	94.2	30.0	11.2
T ₁₈ - APSA (1.0 ml/l)	261.6	77.4	27.5	10.2
T ₁₉ - APSA (2.0 ml/l)	282.2	79.1	27.8	10.2
T ₂₀ - Control	253.6	77.2	27.4	10.2
Mean	305.6	84.6	28.8	10.7
SEm±	6.32	0.90	0.83	0.30
CD (5%)	18.26	2.61	2.41	0.86

APSA = All Purpose Spray Adjuvant

Table 30. Effect of seed hardening and agrochemicals on leaf area ratio (LAR, cm² g⁻¹) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing			
	45	90	120	At Harvest
T ₁ - CaCl ₂ (2%)	259.30	59.97	22.61	10.57
T ₂ - MgSO ₄ (100 ppm)	242.16	58.63	22.05	10.45
T ₃ - ZnSO ₄ (100 ppm)	234.06	57.48	21.91	10.25
T ₄ - KH ₂ PO ₄ (1%)	218.64	55.85	21.69	9.98
T ₅ - CCC (100 ppm)	246.64	59.08	22.22	10.49
T ₆ - KCl (100 ppm)	222.54	56.23	21.74	9.97
T ₇ - Ascorbic acid (20 ppm)	253.57	59.79	22.50	10.53
T ₈ - Cobalt nitrate (1000 ppm)	230.55	57.14	21.84	10.07
T ₉ - Sodium molybdate (100 ppm)	226.59	56.38	21.73	9.97
T ₁₀ - Mixtalol (10 ppm)	239.19	58.21	21.96	10.32
T ₁₁ - MgSO ₄ (0.5%)	262.70	60.20	22.66	10.66
T ₁₂ - CCC (500 ppm)	269.11	65.54	22.96	10.71
T ₁₃ - NAA (20 ppm)	273.74	68.03	24.31	10.94
T ₁₄ - NAA (40 ppm)	283.71	71.03	25.35	11.00
T ₁₅ - Triacantanol (20 ppm)	268.30	67.05	23.07	10.76
T ₁₆ - Miraculan (2.0 ml/l)	306.75	70.79	25.56	11.02
T ₁₇ - Cytozyme (2.0 ml/l)	269.15	67.83	23.56	10.91
T ₁₈ - APSA (1.0 ml/l)	211.31	55.67	21.58	9.97
T ₁₉ - APSA (2.0 ml/l)	229.97	56.90	21.80	10.00
T ₂₀ - Control	205.99	55.57	21.47	9.95
Mean	247.70	60.87	22.63	10.43
SEm±	4.43	0.63	0.61	0.26
CD (5%)	12.80	1.83	1.78	0.76

APSA = All Purpose Spray Adjuvant

Table 31. Effect of seed hardening and agrochemicals on leaf area duration (LAD) at different growth stages in pigeonpea (2004-05)

Treatment	LAD (days)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	139.8	141.4	345.3
T ₂ - MgSO ₄ (100 ppm)	139.1	141	344.3
T ₃ - ZnSO ₄ (100 ppm)	138.6	140.6	343.5
T ₄ - KH ₂ PO ₄ (1%)	138.1	140.3	342.8
T ₅ - CCC (100 ppm)	139.3	141.1	344.6
T ₆ - KCl (100 ppm)	138.1	140.3	342.9
T ₇ - Ascorbic acid (20 ppm)	139.6	141.3	345
T ₈ - Cobalt nitrate (1000 ppm)	138.5	140.6	343.4
T ₉ - Sodium molybdate (100 ppm)	138.2	140.4	343
T ₁₀ - Mixtalol (10 ppm)	138.7	140.7	343.7
T ₁₁ – MgSO ₄ (0.5%)	141.1	142.3	347.2
T ₁₂ - CCC (500 ppm)	141.5	142.6	347.8
T ₁₃ - NAA (20 ppm)	143.7	144.1	351.1
T ₁₄ - NAA (40 ppm)	144.2	144.4	351.7
T ₁₅ - Triacantanol (20 ppm)	143.2	143.7	350.3
T ₁₆ - Miraculan (2.0 ml/l)	144.5	144.6	352.2
T ₁₇ - Cytoszyme (2.0 ml/l)	143.5	143.9	350.8
T ₁₈ - APSA (1.0 ml/l)	137.8	140.1	342.4
T ₁₉ - APSA (2.0 ml/l)	138.3	140.4	343
T ₂₀ - Control	135.3	138.5	338.8
Mean	140.1	141.6	345.7
SEm±	1.44	0.75	1.09
CD (5%)	4.16	2.18	3.16

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 32. Effect of seed hardening and agrochemicals on leaf area duration (LAD) at different growth stages in pigeonpea (2005-06)

Treatment	LAD (days)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	110.4	96.2	132.0
T ₂ - MgSO ₄ (100 ppm)	105.0	92.5	127.4
T ₃ - ZnSO ₄ (100 ppm)	101.3	90.2	124.6
T ₄ - KH ₂ PO ₄ (1%)	96.2	87.4	121.3
T ₅ - CCC (100 ppm)	106.4	93.7	128.9
T ₆ - KCl (100 ppm)	97.2	88.0	121.6
T ₇ - Ascorbic acid (20 ppm)	108.8	95.4	130.9
T ₈ - Cobalt nitrate (1000 ppm)	100.3	89.6	123.3
T ₉ - Sodium molybdate (100 ppm)	98.0	88.2	121.7
T ₁₀ - Mixtalol (10 ppm)	103.1	91.2	125.4
T ₁₁ – MgSO ₄ (0.5%)	114.4	99.3	136.4
T ₁₂ - CCC (500 ppm)	123.2	105.7	139.1
T ₁₃ - NAA (20 ppm)	134.0	116.4	153.0
T ₁₄ - NAA (40 ppm)	141.1	122.6	159.2
T ₁₅ - Triacantanol (20 ppm)	130.2	111.4	145.2
T ₁₆ - Miraculan (2.0 ml/l)	144.5	123.6	161.3
T ₁₇ - Cytozyme (2.0 ml/l)	132.6	114.0	149.1
T ₁₈ - APSA (1.0 ml/l)	94.7	86.5	120.1
T ₁₉ - APSA (2.0 ml/l)	99.2	88.9	122.2
T ₂₀ - Control	88.7	81.6	113.3
Mean	111.5	98.1	132.8
SEm±	1.09	0.77	0.96
CD (5%)	3.16	2.24	2.78

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 33. Effect of seed hardening and agrochemicals on biomass duration (BMD) at different growth stages in pigeonpea (2004-05)

Treatment	BMD (g days)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	1791	3651	12392
T ₂ - MgSO ₄ (100 ppm)	1764	3598	12212
T ₃ - ZnSO ₄ (100 ppm)	1745	3558	12076
T ₄ - KH ₂ PO ₄ (1%)	1725	3518	11940
T ₅ - CCC (100 ppm)	1773	3615	12272
T ₆ - KCl (100 ppm)	1727	3522	11955
T ₇ - Ascorbic acid (20 ppm)	1784	3638	12347
T ₈ - Cobalt nitrate (1000 ppm)	1740	3549	12046
T ₉ - Sodium molybdate (100 ppm)	1730	3527	11970
T ₁₀ - Mixtalol (10 ppm)	1749	3567	12106
T ₁₁ – MgSO ₄ (0.5%)	1843	3757	12754
T ₁₂ - CCC (500 ppm)	1860	3793	12875
T ₁₃ - NAA (20 ppm)	1956	3989	13538
T ₁₄ - NAA (40 ppm)	1976	4028	13674
T ₁₅ - Triacantanol (20 ppm)	1932	3940	13372
T ₁₆ - Miraculan (2.0 ml/l)	1989	4055	13764
T ₁₇ - Cytozyme (2.0 ml/l)	1947	3971	13478
T ₁₈ - APSA (1.0 ml/l)	1714	3495	11865
T ₁₉ - APSA (2.0 ml/l)	1732	3531	11985
T ₂₀ - Control	1623	3309	11231
Mean	1805	3680	12493
SEm±	39	64	110
CD (5%)	112	186	319

APSA = All Purpose Spray Adjuvant

Table 34. Effect of seed hardening and agrochemicals on biomass duration (BMD) at different growth stages in pigeonpea (2005-06)

Treatment	BMD (g days)		
	45 – 90 DAS	90 – 120 DAS	120 DAS - Harvest
T ₁ - CaCl ₂ (2%)	2592	5040	14597
T ₂ - MgSO ₄ (100 ppm)	2553	4965	14383
T ₃ - ZnSO ₄ (100 ppm)	2524	4909	14220
T ₄ - KH ₂ PO ₄ (1%)	2495	4853	14060
T ₅ - CCC (100 ppm)	2563	4988	14453
T ₆ - KCl (100 ppm)	2498	4862	14080
T ₇ - Ascorbic acid (20 ppm)	2579	5021	14543
T ₈ - Cobalt nitrate (1000 ppm)	2517	4897	14185
T ₉ - Sodium molybdate (100 ppm)	2501	4868	14100
T ₁₀ - Mixtalol (10 ppm)	2530	4922	14255
T ₁₁ – MgSO ₄ (0.5%)	2667	5187	15024
T ₁₂ - CCC (500 ppm)	2690	5234	15164
T ₁₃ - NAA (20 ppm)	2830	5505	15945
T ₁₄ - NAA (40 ppm)	2859	5559	16105
T ₁₅ - Triacantanol (20 ppm)	2794	5437	15751
T ₁₆ - Miraculan (2.0 ml/l)	2875	5596	16213
T ₁₇ - Cytozyme (2.0 ml/l)	2817	5478	15871
T ₁₈ - APSA (1.0 ml/l)	2482	4824	13975
T ₁₉ - APSA (2.0 ml/l)	2504	4874	14115
T ₂₀ - Control	2345	4566	13229
Mean	2611	5079	14713
SEm± CD (5%)	43 125	67 195	123 355

APSA = All Purpose Spray Adjuvant

During 2004-05 treatment with miraculan (2.0 ml/l) registered higher BMD followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) at all the stages. However, these were on par with each other. Among seed hardening treatments, CaCl_2 (2 %) recorded higher BMD followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However the lesser BMD was recorded in control.

Similar trend was noticed during 2005-06. The treatment with miraculan (2.0 ml/l) recorded higher BMD followed by NAA (40 ppm), NAA (20 ppm) and triacontanol (20 ppm) at all the stages. However, these were on par with each other. Among seed hardening chemicals, the same trend was observed. In general the over all values of BMD were more during second year compared to first year. However, the lower BMD was recorded in control.

4.3 BIOPHYSICAL AND BIOCHEMICAL PARAMETERS

4.3.1 Relative water content (%)

The data on relative water content (RWC) as influenced by plant growth regulators and seed hardening chemicals showed significant difference among the treatments at both the stages (90 and 120 DAS) during both the years (Table 35 and 36). In general relative water content was increased at 90 DAS and decreased thereafter.

During first year (2004-05), the treatment with miraculan (2.0 ml/l) registered higher relative water content followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). However, these were on par with each other at 90 DAS while, NAA (40 ppm) is on par with miraculan (2.0 ml/l) at 120 DAS. Among the seed hardening chemicals, ascorbic acid (20 ppm) recorded higher RWC at both 90 and 120 DAS followed by CaCl_2 (2 %), CCC (100 ppm) and MgSO_4 (100 ppm). However, the lower RWC was recorded in control.

During second year (2005-06), the same trend was observed. The treatment miraculan (2.0 ml/l) recorded higher RWC followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) but these were on par with the each other. Among the seed hardening chemicals, ascorbic acid (20 ppm) recorded higher RWC followed by CaCl_2 (2 %), CCC (100 ppm) and MgSO_4 (100 ppm). In general RWC values were more in second year compared to first year. The lower value of RWC recorded in control.

4.3.2 Chlorophyll 'a' content (mg. g⁻¹ fresh weight)

Data (Table 37 and 38) pertaining to chlorophyll 'a' content as influenced by plant growth regulator and agrochemicals showed significant difference at 90 DAS and 120 DAS during both the years. In general chlorophyll 'a' content is more during 2005-06 compared to 2004-05 and the chlorophyll content is maximum at 90 DAS compared to 120 DAS.

During 2004-05, the treatment with NAA (20 ppm) recorded maximum chlorophyll 'a' content followed by cytozyme (2.0 ml/l), NAA (40 ppm) and miraculan (2.0 ml/l) at 90 DAS however; these were on par with each other. At 120 DAS, the treatment with miraculan (2.0 ml/l) recorded higher chlorophyll 'a' content followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening chemicals, the treatment with KCl (100 ppm) registered maximum chlorophyll 'a' content followed by CaCl_2 (2 %), CCC (100 ppm) and ZnSO_4 (100 ppm). At 120 DAS ascorbic acid (20 ppm) recorded higher chlorophyll content followed by CCC (100 ppm) and CaCl_2 (2 %). However, the lower chlorophyll 'a' content was recorded in control.

During 2005-06, the treatment with NAA (20 ppm) recorded higher chlorophyll 'a' content followed by cytozyme (2.0 ml/l) and NAA (40 ppm) at 90 DAS and at 120 DAS,

Table 35. Effect of seed hardening and agrochemicals on relative water content (%) at different growth stages in pigeonpea (2004-05)

Treatment	Days after sowing	
	90	120
T ₁ - CaCl ₂ (2%)	77.4	63.4
T ₂ - MgSO ₄ (100 ppm)	76.4	62.1
T ₃ - ZnSO ₄ (100 ppm)	75.5	60.6
T ₄ - KH ₂ PO ₄ (1%)	73.6	60.4
T ₅ - CCC (100 ppm)	76.6	62.9
T ₆ - KCl (100 ppm)	74.2	61.7
T ₇ - Ascorbic acid (20 ppm)	78.5	64.7
T ₈ - Cobalt nitrate (1000 ppm)	72.4	61.3
T ₉ - Sodium molybdate (100 ppm)	75.2	60.3
T ₁₀ - Mixtalol (10 ppm)	77.3	63.2
T ₁₁ - MgSO ₄ (0.5%)	79.4	63.9
T ₁₂ - CCC (500 ppm)	79.5	65.3
T ₁₃ - NAA (20 ppm)	82.9	71.4
T ₁₄ - NAA (40 ppm)	83.3	72.7
T ₁₅ - Triacantanol (20 ppm)	80.8	68.4
T ₁₆ - Miraculan (2.0 ml/l)	83.7	73.5
T ₁₇ - Cytozyme (2.0 ml/l)	81.6	71.9
T ₁₈ - APSA (1.0 ml/l)	71.7	61.2
T ₁₉ - APSA (2.0 ml/l)	76.3	61.8
T ₂₀ - Control	70.0	59.3
Mean	77.3	64.5
SEm±	0.63	0.36
CD (5%)	1.83	1.03

APSA = All Purpose Spray Adjuvant

Table 36. Effect of seed hardening and agrochemicals on relative water content (%) at different growth stages in pigeonpea (2005-06)

Treatment	Days after sowing	
	90	120
T ₁ - CaCl ₂ (2%)	82.12	64.58
T ₂ - MgSO ₄ (100 ppm)	80.97	63.18
T ₃ - ZnSO ₄ (100 ppm)	80.14	61.67
T ₄ - KH ₂ PO ₄ (1%)	78.15	61.47
T ₅ - CCC (100 ppm)	81.30	64.04
T ₆ - KCl (100 ppm)	78.70	62.75
T ₇ - Ascorbic acid (20 ppm)	83.30	65.87
T ₈ - Cobalt nitrate (1000 ppm)	76.76	62.33
T ₉ - Sodium molybdate (100 ppm)	79.75	61.35
T ₁₀ - Mixtalol (10 ppm)	81.96	64.36
T ₁₁ – MgSO ₄ (0.5%)	84.29	65.01
T ₁₂ - CCC (500 ppm)	84.40	66.51
T ₁₃ - NAA (20 ppm)	88.06	72.86
T ₁₄ - NAA (40 ppm)	88.06	74.16
T ₁₅ - Triacantanol (20 ppm)	85.73	69.74
T ₁₆ - Miraculan (2.0 ml/l)	88.94	75.01
T ₁₇ - Cytozyme (2.0 ml/l)	86.62	73.30
T ₁₈ - APSA (1.0 ml/l)	75.99	62.21
T ₁₉ - APSA (2.0 ml/l)	80.97	62.86
T ₂₀ - Control	74.22	60.28
Mean	82.02	65.68
SEm±	0.74	0.36
CD (5%)	2.13	1.06

APSA = All Purpose Spray Adjuvant

miraculan (2.0 ml/l) registered higher chlorophyll 'a' content followed by NAA (40 ppm) and NAA (20 ppm). Among seed hardening chemicals, treatment with KCl (100 ppm) recorded higher chlorophyll 'a' content followed by CaCl_2 (2 %), ascorbic acid (20 ppm) and CCC (100 ppm) at 90 DAS and at 120 DAS, ascorbic acid (20 ppm) recorded higher chlorophyll 'a' content followed by CCC (100 ppm) and CaCl_2 (2 %). However, lower value of chlorophyll 'a' content was recorded in control.

4.3.3 Chlorophyll 'b' content (mg. g-1 fresh weight)

The data on chlorophyll 'b' content showed significant difference due to the influence of plant growth regulators and seed hardening chemicals at 90 and 120 DAS during both the years (Table 37 and 38).

During first year (2004-05), the chlorophyll 'b' content was higher at 90 DAS. The treatment with MgSO_4 (0.5%) recorded higher chlorophyll 'b' content followed by miraculan (2.0 ml/l), NAA (40 ppm) and triacontanol (20 ppm) at 90 DAS and at 120 DAS, the treatment with NAA (20 ppm) registered higher chlorophyll 'b' content followed by cytozyme (2.0 ml/l), CCC (500 ppm) and triacontanol (20 ppm). Among seed hardening chemicals, the treatment with ascorbic acid (20 ppm) recorded higher chlorophyll 'b' content followed by CCC (100 ppm), MgSO_4 (100 ppm) and sodium molybdate (100 ppm) at 90 DAS and at 120 DAS, the treatment with MgSO_4 (100 ppm), mixtalol (10 ppm) and cobalt nitrate (1000 ppm). However, these were on par with each other. The lower chlorophyll 'b' content was recorded in control.

During second year (2005-06), at 90 DAS, the treatment with MgSO_4 (0.5%) registered higher chlorophyll 'b' content followed by miraculan (2.0 ml/l), NAA (40 ppm) and triacontanol (20 ppm). At 120 DAS, the treatment with NAA (20 ppm) recorded higher chlorophyll 'b' content followed by cytozyme (2.0 ml/l), triacontanol (20 ppm) and CCC (500 ppm). Among seed hardening chemicals, the treatment with ascorbic acid (20 ppm) and CCC (500 ppm) recorded higher chlorophyll 'b' content followed by CCC (100 ppm), MgSO_4 (100 ppm) and KCl (100 ppm) at 90 DAS and at 120 DAS, the treatment with MgSO_4 (100 ppm) registered higher chlorophyll 'b' content followed by CaCl_2 (2 %), mixtalol (10 ppm) and cobalt nitrate (1000 ppm). However, the lower value of chlorophyll 'b' content is recorded in control.

4.3.4 Total chlorophyll content (mg. g-1 fresh weight)

The data on total chlorophyll content (Table 37 and 38) revealed that, there was significant difference at 90 and 120 DAS during both the years. In general the total chlorophyll content was more during second year compared to first year.

During 2004-05, the total chlorophyll content was more in the treatment NAA (40 ppm) followed by miraculan (2.0 ml/l), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) but it was on par with miraculan (2.0 ml/l) at 90 DAS and at 120 DAS, the treatment with miraculan (2.0 ml/l) recorded higher total chlorophyll content followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and CCC (500 ppm). Among seed hardening chemicals, the treatment with KCl (100 ppm) recorded higher total chlorophyll content followed by CaCl_2 (2 %), CCC (100 ppm) and CCC (100 ppm) at 90 DAS and at 120 DAS, the treatment with CaCl_2 (2 %) recorded higher total chlorophyll content followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, the lower total chlorophyll content recorded in control.

During 2005-06, the treatment with NAA (40 ppm) registered higher total chlorophyll content followed by miraculan (2.0 ml/l), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) and it was on par with miraculan (2.0 ml/l). At 120 DAS, the treatment with miraculan (2.0 ml/l) recorded higher total chlorophyll content followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm).

Among the seed hardening chemicals, the treatment with KCl (100 ppm) registered higher total chlorophyll content followed by ascorbic acid (20 ppm), CaCl_2 (2 %) and CCC

Table 37. Effect of seed hardening and agrochemicals on chlorophyll content at 90 and 120 DAS (mg/g fresh weight) in pigeonpea (2004-05)

Treatment	Chlorophyll 'a'		Chlorophyll 'b'		Total chlorophyll	
	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS
T ₁ - CaCl ₂ (2%)	1.19	0.75	0.28	0.26	1.47	1.01
T ₂ - MgSO ₄ (100 ppm)	1.00	0.63	0.40	0.27	1.40	0.90
T ₃ - ZnSO ₄ (100 ppm)	1.01	0.72	0.31	0.15	1.32	0.87
T ₄ - KH ₂ PO ₄ (1%)	0.84	0.52	0.34	0.12	1.18	0.64
T ₅ - CCC (100 ppm)	1.03	0.76	0.42	0.16	1.44	0.92
T ₆ - KCl (100 ppm)	1.55	0.45	0.39	0.20	1.94	0.65
T ₇ - Ascorbic acid (20 ppm)	1.04	0.79	0.43	0.16	1.47	0.95
T ₈ - Cobalt nitrate (1000 ppm)	0.96	0.60	0.32	0.23	1.28	0.83
T ₉ - Sodium molybdate (100 ppm)	0.84	0.57	0.36	0.12	1.20	0.69
T ₁₀ - Mixtalol (10 ppm)	1.00	0.63	0.34	0.25	1.34	0.88
T ₁₁ - MgSO ₄ (0.5%)	1.04	0.75	0.46	0.30	1.50	1.05
T ₁₂ - CCC (500 ppm)	1.30	0.76	0.25	0.31	1.55	1.07
T ₁₃ - NAA (20 ppm)	1.52	0.78	0.27	0.35	1.79	1.13
T ₁₄ - NAA (40 ppm)	1.45	1.05	0.42	0.23	1.87	1.28
T ₁₅ - Triacontanol (20 ppm)	1.35	0.77	0.32	0.31	1.67	1.08
T ₁₆ - Miraculan (2.0 ml/l)	1.40	1.22	0.43	0.24	1.83	1.46
T ₁₇ - Cytozyme (2.0 ml/l)	1.50	0.78	0.26	0.32	1.76	1.10
T ₁₈ - APSA (1.0 ml/l)	0.80	0.50	0.30	0.12	1.10	0.62
T ₁₉ - APSA (2.0 ml/l)	1.02	0.51	0.20	0.20	1.22	0.71
T ₂₀ - Control	0.60	0.45	0.26	0.13	0.86	0.58
Mean	1.12	0.70	0.34	0.22	1.46	0.92
SEm±						
CD (5%)	0.15	0.10	0.05	0.11	0.22	0.14
	0.42	0.29	0.14	0.31	0.63	0.39

APSA = All Purpose Spray Adjuvant

Table 38. Effect of seed hardening and agrochemicals on chlorophyll content at 90 and 120 DAS (mg/g fresh weight) in pigeonpea (2005-06)

Treatment	Chlorophyll 'a'		Chlorophyll 'b'		Total chlorophyll	
	90 DAS	120 DAS	90 DAS	120 DAS	90 DAS	120 DAS
T ₁ - CaCl ₂ (2%)	1.57	1.04	0.41	0.35	1.99	1.39
T ₂ - MgSO ₄ (100 ppm)	1.32	0.87	0.60	0.36	1.92	1.24
T ₃ - ZnSO ₄ (100 ppm)	1.34	0.99	0.45	0.20	1.79	1.20
T ₄ - KH ₂ PO ₄ (1%)	1.11	0.72	0.49	0.16	1.61	0.88
T ₅ - CCC (100 ppm)	1.36	1.05	0.61	0.21	1.97	1.27
T ₆ - KCl (100 ppm)	2.05	0.62	0.57	0.26	2.63	0.89
T ₇ - Ascorbic acid (20 ppm)	1.37	1.09	0.63	0.21	2.01	1.31
T ₈ - Cobalt nitrate (1000 ppm)	1.27	0.83	0.46	0.31	1.74	1.14
T ₉ - Sodium molybdate (100 ppm)	1.11	0.79	0.53	0.16	1.64	0.95
T ₁₀ - Mixtalol (10 ppm)	1.32	0.87	0.51	0.34	1.83	1.21
T ₁₁ - MgSO ₄ (0.5%)	1.38	1.04	0.68	0.41	2.06	1.45
T ₁₂ - CCC (500 ppm)	1.72	1.05	0.37	0.42	2.09	1.47
T ₁₃ - NAA (20 ppm)	2.01	1.08	0.40	0.47	2.41	1.55
T ₁₄ - NAA (40 ppm)	1.92	1.45	0.62	0.31	2.54	1.76
T ₁₅ - Triacantanol (20 ppm)	1.78	1.06	0.47	0.42	2.26	1.49
T ₁₆ - Miraculan (2.0 ml/l)	1.85	1.69	0.63	0.32	2.49	2.01
T ₁₇ - Cytozyme (2.0 ml/l)	1.98	1.08	0.38	0.43	2.37	1.52
T ₁₈ - APSA (1.0 ml/l)	1.06	0.69	0.45	0.16	1.51	0.85
T ₁₉ - APSA (2.0 ml/l)	1.35	0.70	0.29	0.26	1.64	0.97
T ₂₀ - Control	0.79	0.62	0.38	0.17	1.18	0.80
Mean	1.48	0.97	0.50	0.30	1.98	1.27
SEm±	0.19	0.11	0.06	0.13	0.25	0.14
CD (5%)	0.56	0.33	0.19	0.39	0.74	0.42

APSA = All Purpose Spray Adjuvant

(100 ppm). At 120 DAS, the higher total chlorophyll content was recorded in the treatment CaCl_2 (2 %) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, these were on par with each other. The lower total chlorophyll content was observed in control.

4.3.5 Proline content ($\mu\text{mol g}^{-1}\text{ fr. wt.}$)

It was evident from the data that proline content as influenced by plant height regulators and seed hardening chemicals showed significant differences at 90 and 120 DAS during both the years (Table 39 and 40). In general the proline content was more during 2004-05 compared to 2005-06.

During first year (2004-05) at 90 DAS, the treatment with miraculan (2.0 ml/l) recorded higher proline content followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). However, miraculan (2.0 ml/l) is on par with NAA (40 ppm). At 120 DAS, the same trend was followed. Among seed hardening chemicals, higher proline content was registered in mixtalol (10 ppm) followed by ascorbic acid (20 ppm), cobalt nitrate (1000 ppm) and KH_2PO_4 (1 %). However, mixtalol (10 ppm) recorded higher proline content followed by ascorbic acid (20 ppm) at 90 DAS and at 120 DAS, the treatment with mixtalol (10 ppm) recorded higher proline content followed by ascorbic acid (20 ppm), CaCl_2 (2 %), cobalt nitrate (1000 ppm) and MgSO_4 (100 ppm). However, mixtalol (10 ppm) is on par with ascorbic acid (20 ppm). The lower proline content was registered in control.

During second year (2005-06), a same trend was observed. Among seed hardening chemicals, treatment with mixtalol (10 ppm) is on par with ascorbic acid (20 ppm) at both 90 DAS and 120 DAS. In general the proline content was more during 2004-05 compared to 2005-06. However the lower proline content was recorded in control.

4.3.6 Nitrate reductase activity ($\mu\text{mol NO}_2\text{ g}^{-1}\text{ fr. wt}^{-1}\text{ hr}^{-1}$)

The data on nitrate reductase activity indicated significant difference as influenced by plant growth regulators and seed hardening chemicals at 90 and 120 DAS during both the years (Table 39 and 40). In general the nitrate reductase activity more at 90 DAS compared to 120 DAS and it was reduced as the age of the crop advanced.

During 2004-05, the treatment with NAA (40 ppm) registered higher nitrate reductase activity followed by miraculan (2.0 ml/l), triacontanol (20 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l) at 90 DAS and at 120 DAS, miraculan (2.0 ml/l) recorded maximum nitrate reductase activity followed by NAA (40 ppm), triacontanol (20 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l). However, miraculan (2.0 ml/l) is on par with NAA (40 ppm). Among seed hardening chemicals, KCl (100 ppm) registered higher nitrate reductase activity followed by mixtalol (10 ppm), CCC (100 ppm) and CaCl_2 (2 %) at 90 DAS and at 120 DAS, the treatment with mixtalol (10 ppm) recorded higher activity of nitrate reductase followed by CaCl_2 (2 %), sodium molybdate (100 ppm), ascorbic acid (20 ppm) and MgSO_4 (100 ppm). However, the lower activity of nitrate reductase observed in control.

During 2005-06, the treatment with NAA (40 ppm) recorded higher nitrate reductase activity followed by miraculan (2.0 ml/l), triacontanol (20 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l). The same trend was observed at 120 DAS but they were on par with each other. Among seed hardening chemicals, KCl (100 ppm) registered higher activity of nitrate reductase followed by mixtalol (10 ppm), CCC (100 ppm) and CaCl_2 (2 %). At 90 DAS, the treatment with mixtalol (10 ppm) recorded higher nitrate reductase activity followed by CaCl_2 (2 %), sodium molybdate (100 ppm), ascorbic acid (20 ppm) and cobalt nitrate (1000 ppm). However, these were on par with each other. The lower activity of nitrate reductase was observed in control.

Table 39. Effect of seed hardening and agrochemicals on proline content and nitrate reductase activity at different growth stages in pigeonpea (2004-05)

Treatment	Proline content ($\mu\text{mol g fr.wt.}^{-1}$)		NRA ($\mu\text{mol NO}_2/\text{g fr.wt.}^{-1} \text{ hr}^{-1}$)	
	90 DAS	120 DAS	90 DAS	120 DAS
T ₁ - CaCl ₂ (2%)	9.00	12.01	240.8	202.8
T ₂ - MgSO ₄ (100 ppm)	8.23	11.72	236.7	192.7
T ₃ - ZnSO ₄ (100 ppm)	8.23	11.35	231.6	189.6
T ₄ - KH ₂ PO ₄ (1%)	9.31	10.48	228.6	185.6
T ₅ - CCC (100 ppm)	9.36	11.23	244.9	188.6
T ₆ - KCl (100 ppm)	9.26	10.35	249.9	179.5
T ₇ - Ascorbic acid (20 ppm)	9.92	12.32	237.7	198.7
T ₈ - Cobalt nitrate (1000 ppm)	9.66	12.00	233.7	194.7
T ₉ - Sodium molybdate (100 ppm)	9.55	11.25	235.7	199.8
T ₁₀ - Mixtalol (10 ppm)	10.17	12.77	248.9	202.8
T ₁₁ - MgSO ₄ (0.5%)	10.38	12.39	238.8	212.9
T ₁₂ - CCC (500 ppm)	10.67	12.92	243.8	219.0
T ₁₃ - NAA (20 ppm)	12.33	15.93	261.1	223.1
T ₁₄ - NAA (40 ppm)	12.87	16.16	285.5	234.2
T ₁₅ - Triaccontanol (20 ppm)	11.31	14.71	264.2	228.2
T ₁₆ - Miraculan (2.0 ml/l)	13.39	16.44	273.3	236.3
T ₁₇ - Cytozyme (2.0 ml/l)	11.82	14.50	257.0	223.1
T ₁₈ - APSA (1.0 ml/l)	8.14	11.49	226.6	196.7
T ₁₉ - APSA (2.0 ml/l)	8.35	11.61	231.6	200.8
T ₂₀ - Control	7.79	10.27	228.6	171.4
Mean	9.98	12.59	244.9	204.1
SEm $\pm$	0.73	0.75	0.64	2.29
CD (5%)	2.12	2.18	1.86	6.61

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

Table 40. Effect of seed hardening and agrochemicals on proline content and nitrate reductase activity at different growth stages in pigeonpea (2005-06)

Treatment	Proline content ($\mu\text{mol g fr.wt.}^{-1}$)		NRA ($\mu\text{mol NO}_2/\text{g fr.wt.}^{-1} \text{ hr}^{-1}$)	
	90 DAS	120 DAS	90 DAS	120 DAS
T ₁ - CaCl ₂ (2%)	8.39	11.66	253	209
T ₂ - MgSO ₄ (100 ppm)	7.59	11.35	248	198
T ₃ - ZnSO ₄ (100 ppm)	7.59	10.97	242	195
T ₄ - KH ₂ PO ₄ (1%)	8.71	10.05	239	191
T ₅ - CCC (100 ppm)	8.76	10.84	256	194
T ₆ - KCl (100 ppm)	8.65	9.92	262	185
T ₇ - Ascorbic acid (20 ppm)	9.34	11.98	249	205
T ₈ - Cobalt nitrate (1000 ppm)	9.07	11.65	245	200
T ₉ - Sodium molybdate (100 ppm)	8.96	10.86	247	206
T ₁₀ - Mixtalol (10 ppm)	9.60	12.46	261	209
T ₁₁ - MgSO ₄ (0.5%)	9.82	12.06	250	219
T ₁₂ - CCC (500 ppm)	10.12	12.61	255	226
T ₁₃ - NAA (20 ppm)	11.85	15.78	273	230
T ₁₄ - NAA (40 ppm)	10.51	16.02	299	241
T ₁₅ - Triacantanol (20 ppm)	10.78	14.50	277	235
T ₁₆ - Miraculan (2.0 ml/l)	12.94	16.32	294	243
T ₁₇ - Cytozyme (2.0 ml/l)	11.31	14.28	269	230
T ₁₈ - APSA (1.0 ml/l)	7.49	11.12	237	202
T ₁₉ - APSA (2.0 ml/l)	7.72	11.25	242	207
T ₂₀ - Control	7.14	9.83	239	176
Mean	9.32	12.28	257	210
SEm $\pm$	0.36	0.78	0.93	4.81
CD (5%)	1.06	2.26	2.68	13.91

APSA = All Purpose Spray Adjuvant
DAS: Days after sowing

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 at harvest during both the years (Table 41 and 42). In general, more number of pods per plant were observed during second year (2005-06) compared to first year (2004-05).

During first year (2004-05), the maximum number of pods per plant were noticed with treatment miraculan (2.0 ml/l) followed by NAA (40 ppm), cytozyme (2.0 ml/l), NAA (20 ppm) and triacontanol (20 ppm). However, these were on par with each other. It was further noticed that in different concentrations of seed hardening chemicals, the treatment with CaCl_2 (2 %) recorded maximum number of pods per plant followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, these treatments were on par with each other. In general, all the treatments had more number of pods per plant over control.

During second year (2005-06), a similar trend on number of pods was observed and the treatment with miraculan (2.0 ml/l) significantly recorded maximum number of pods per plant followed by NAA (40 ppm), cytozyme (2.0 ml/l), NAA (20 ppm) and triacontanol (20 ppm). Among the seed hardening chemicals, the treatment with CaCl_2 (2 %) recorded more number of pods per plant followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, the lower number of pods per plant was registered in control.

4.4.2 Pod set percent

The data on pod set per cent presented in Table 41 and 42 indicated a significant increase due to treatments over control during both the years. Among the treatments, plant growth regulators recorded higher pod set per cent compared to seed hardening chemicals.

During 2004-05, the treatment with miraculan (2.0 ml/l) recorded higher pod set per cent (20.02) followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening treatments, CaCl_2 (2 %) registered higher pod set per cent (16.92) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, these were on par with each other and the lesser pod set per cent was recorded in control.

Similarly during 2005-06, the treatment with miraculan (2.0 ml/l) recorded maximum pod set per cent (22.65) followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). However, these were on par with each other. Among the seed hardening chemicals, CaCl_2 (2 %) registered higher pod set per cent followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm) but these treatments were on par with each other. However, the lower pod set per cent was observed in control.

4.4.3 Seed yield (g plant⁻¹)

The data on seed yield gram per plant presented in Table 41 and 42 indicated a significant increase due to treatments over control during both the years. In general, more yield was obtained during second year (2005-06) compared to first year (2004-05).

During first year (2004-05), a maximum seed yield of 33.51 gram per plant was obtained with treatment miraculan (2.0 ml/l) which was significantly higher over NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening chemicals CaCl_2 (2 %) registered maximum seed yield of 28.83 gram per plant followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, the lower seed yield of 23.95 gram per plant was noticed in control.



T₁ - Seed hardening with CaCl₂ (2.0%)



T₂ - Seed hardening with MgSO₄ (100 ppm)



T₃ - Seed hardening with ZnSO₄ (100 ppm)



T₄ - Seed hardening with KH₂PO₄ (1.0%)

Plate 2. Influence of seed hardening with nutrients on growth and development in pigeonpea

Table 41. Effect of seed hardening and agrochemicals on yield and yield components in pigeonpea (2004-05)

Treatment	No. of pods	Pod set (%)	Seed yield (g/plant)	Seed yield (kg/ha)
T ₁ - CaCl ₂ (2%)	121.8	16.92	28.83	1602
T ₂ - MgSO ₄ (100 ppm)	119.3	15.91	27.19	1511
T ₃ - ZnSO ₄ (100 ppm)	118.6	15.21	26.86	1492
T ₄ - KH ₂ PO ₄ (1%)	117.7	13.01	24.89	1383
T ₅ - CCC (100 ppm)	120.2	16.06	27.29	1516
T ₆ - KCl (100 ppm)	117.4	13.42	25.20	1400
T ₇ - Ascorbic acid (20 ppm)	120.9	16.43	27.59	1533
T ₈ - Cobalt nitrate (1000 ppm)	118.6	14.82	26.33	1463
T ₉ - Sodium molybdate (100 ppm)	117.8	13.86	25.38	1410
T ₁₀ - Mixtalol (10 ppm)	118.6	15.47	27.02	1501
T ₁₁ - MgSO ₄ (0.5%)	125.7	17.34	28.85	1603
T ₁₂ - CCC (500 ppm)	127.0	17.66	28.98	1610
T ₁₃ - NAA (20 ppm)	133.7	18.82	30.60	1700
T ₁₄ - NAA (40 ppm)	136.1	19.21	30.94	1719
T ₁₅ - Triacontanol (20 ppm)	133.5	17.84	29.25	1625
T ₁₆ - Miraculan (2.0 ml/l)	137.2	20.02	33.51	1862
T ₁₇ - Cytozyme (2.0 ml/l)	134.7	18.65	29.81	1656
T ₁₈ - APSA (1.0 ml/l)	116.5	12.73	24.50	1361
T ₁₉ - APSA (2.0 ml/l)	117.4	14.30	25.42	1412
T ₂₀ - Control	109.2	12.21	23.95	1333
Mean	123.1	15.99	27.62	1534
SEm±	1.56	0.56	0.77	33.39
CD (5%)	4.52	1.63	2.22	96.50

APSA = All Purpose Spray Adjuvant

Table 42. Effect of seed hardening and agrochemicals on yield and yield components in pigeonpea (2005-06)

Treatment	No. of pods	Pod set (%)	Seed yield (g/plant)	Seed yield (kg/ha)
T ₁ - CaCl ₂ (2%)	124.7	18.75	35.17	1954
T ₂ - MgSO ₄ (100 ppm)	122.1	17.41	32.09	1783
T ₃ - ZnSO ₄ (100 ppm)	121.4	16.77	32.22	1790
T ₄ - KH ₂ PO ₄ (1%)	120.5	15.22	29.63	1646
T ₅ - CCC (100 ppm)	123.0	17.62	32.47	1804
T ₆ - KCl (100 ppm)	120.2	15.74	30.24	1680
T ₇ - Ascorbic acid (20 ppm)	123.7	18.40	33.39	1855
T ₈ - Cobalt nitrate (1000 ppm)	121.4	16.38	31.34	1741
T ₉ - Sodium molybdate (100 ppm)	120.6	15.92	30.20	1678
T ₁₀ - Mixtalol (10 ppm)	121.4	17.10	32.69	1816
T ₁₁ - MgSO ₄ (0.5%)	128.6	19.22	34.33	1907
T ₁₂ - CCC (500 ppm)	129.9	19.67	35.06	1948
T ₁₃ - NAA (20 ppm)	136.9	21.06	36.72	2040
T ₁₄ - NAA (40 ppm)	139.3	21.74	37.44	2080
T ₁₅ - Triacntanol (20 ppm)	136.7	20.25	35.10	1950
T ₁₆ - Miraculan (2.0 ml/l)	145.4	22.65	40.88	2271
T ₁₇ - Cytozyme (2.0 ml/l)	137.9	20.76	35.48	1971
T ₁₈ - APSA (1.0 ml/l)	119.3	14.85	29.16	1620
T ₁₉ - APSA (2.0 ml/l)	120.2	16.20	29.98	1666
T ₂₀ - Control	119.8	14.64	28.55	1586
Mean	126.6	18.02	33.11	1839
SEm±	1.25	0.55	1.07	20.29
CD (5%)	3.61	1.59	3.09	58.65

APSA = All Purpose Spray Adjuvant



T₅ - Seed hardening with CCC (100 ppm)



T₆ - Seed hardening with KCl (100 ppm)



**T₇ - Seed hardening with Ascorbic acid
(20 ppm)**



**T₈ - Seed hardening with Cobalt nitrate
(1000 ppm)**

Plate 3. Influence of seed hardening with nutrients and growth regulators on growth and development in pigeonpea

During second year (2005-06), the treatment with miraculan (2.0 ml/l) recorded higher seed yield of 40.88 gram per plant followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening chemicals, CaCl_2 (2 %) registered maximum yield of 35.17 gram per plant followed by ascorbic acid (20 ppm), CCC (100 ppm) and ZnSO_4 (100 ppm). However, these were on par with each other. The lower seed yield of 28.55 gram per plant was obtained in control.

4.4.4 Seed yield (kg ha⁻¹)

Results on seed yield revealed that, treatments differed significantly as influenced by plant growth regulators and seed hardening chemicals during both the years (Table 41 and 42). In general the higher seed yield was noticed during second year (2005-06) compared to first year (2004-05).

During first year (2004-05), a maximum seed yield of 1862 kg per hectare was obtained with treatment miraculan (2.0 ml/l) which was significantly higher over NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening chemicals, CaCl_2 (2 %) registered higher seed yield of 1602 kg per hectare followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, the lower seed yield of 1333 kg per hectare was noticed in control.

Similarly during second year (2005-06), a same trend was observed and the treatment with miraculan (2.0 ml/l) recorded higher seed yield of 2271 kg per hectare followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm). Among the seed hardening chemicals, CaCl_2 (2 %) registered higher yield of 1954 kg per hectare followed by ascorbic acid (20 ppm), CCC (100 ppm) and ZnSO_4 (100 ppm). However, these were on par with each other. The lower seed yield of 1586 kg per hectare was obtained in control.

4.4.5 Number of seeds per plant

The data on number of seeds per plant as influenced by plant growth regulators and agrochemicals showed significant increase over control during both the years (Table 43 and 44).

During 2004-05, the treatment with miraculan (2.0 ml/l) recorded higher number of seeds per plant (565.2) followed by NAA (40 ppm), cytozyme (2.0 ml/l) and NAA (20 ppm). Among seed hardening chemicals, the treatment with CaCl_2 (2 %) registered higher number of seeds per plant (436.5) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, all these treatments were at par with each other. The lower number of seeds per plant (380.0) was recorded in control.

During 2005-06, the treatment with miraculan (2.0 ml/l) recorded higher number of seeds per plant (619.70) followed by NAA (40 ppm), cytozyme (2.0 ml/l) and NAA (20 ppm). Among seed hardening chemicals, the treatment with CaCl_2 (2 %) recorded higher number of seeds per plant (478.60) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, all these treatments were at par with each other. The lower number of seeds per plant (416.60) was recorded in control.

4.4.6 100 - seed weight

It was noticed from the Table 43 and 44 that, the data pertaining to 100 - seed weight indicated a significant increase due to treatments over control during both the years.

During first year (2004-05), the treatment with miraculan (2.0 ml/l) recorded maximum 100 - seed weight (9.82 g) followed by NAA (40 ppm), cytozyme (2.0 ml/l), NAA (20 ppm) and triacontanol (20 ppm). Amongst the seed hardening treatments, CaCl_2 (2 %) registered



T₉ - Seed hardening with Sodium molybdate (100 ppm)



T₁₀ - Seed hardening with Mixtaol (10 ppm)



T₁₁ - Foliar application of MgSO₄ (0.5%) at 70 & 90 DAS



T₁₂ - Foliar application of CCC (500 ppm) at 70 & 90 DAS

Plate 4. Influence of seed hardening and foliar application of nutrients and growth regulators on growth and development in pigeonpea

Table 43. Effect of seed hardening and agrochemicals on yield and yield components in pigeonpea (2004-05)

Treatment	No. of seeds/ plant	100 Seed weight (g)	No. of seeds/ pod	Harvest index (%)
T ₁ - CaCl ₂ (2%)	436.5	7.58	3.50	14.07
T ₂ - MgSO ₄ (100 ppm)	421.1	7.31	3.45	13.47
T ₃ - ZnSO ₄ (100 ppm)	414.0	7.19	3.41	13.46
T ₄ - KH ₂ PO ₄ (1%)	406.4	7.06	3.37	12.61
T ₅ - CCC (100 ppm)	426.3	7.40	3.47	13.45
T ₆ - KCl (100 ppm)	405.9	7.05	3.38	12.75
T ₇ - Ascorbic acid (20 ppm)	431.4	7.49	3.49	13.52
T ₈ - Cobalt nitrate (1000 ppm)	413.0	7.17	3.40	13.22
T ₉ - Sodium molybdate (100 ppm)	407.7	7.08	3.38	12.82
T ₁₀ - Mixtalol (10 ppm)	415.1	7.21	3.42	13.50
T ₁₁ - MgSO ₄ (0.5%)	463.2	8.05	3.60	13.68
T ₁₂ - CCC (500 ppm)	472.3	8.20	3.64	13.61
T ₁₃ - NAA (20 ppm)	523.5	9.09	3.82	13.67
T ₁₄ - NAA (40 ppm)	538.0	9.34	3.86	13.68
T ₁₅ - Triacantanol (20 ppm)	516.3	8.97	3.78	13.23
T ₁₆ - Miraculan (2.0 ml/l)	565.2	9.82	3.89	14.72
T ₁₇ - Cytozyme (2.0 ml/l)	524.9	9.12	3.81	13.38
T ₁₈ - APSA (1.0 ml/l)	399.8	6.94	3.35	12.49
T ₁₉ - APSA (2.0 ml/l)	406.9	7.07	3.39	12.83
T ₂₀ - Control	380.0	6.60	3.17	12.90
Mean	448.4	7.79	3.53	13.35
SEm±	15.51	0.79	0.035	0.31
CD (5%)	44.81	2.29	0.10	0.89

APSA = All Purpose Spray Adjuvant

Table 44. Effect of seed hardening and agrochemicals on yield and yield components in pigeonpea (2005-06)

Treatment	No. of seeds/ plant	100 Seed weight (g)	No. of seeds/ pod	Harvest index (%)
T ₁ - CaCl ₂ (2%)	436.5	7.58	3.50	13.73
T ₂ - MgSO ₄ (100 ppm)	421.1	7.31	3.45	12.71
T ₃ - ZnSO ₄ (100 ppm)	414.0	7.19	3.41	12.91
T ₄ - KH ₂ PO ₄ (1%)	406.4	7.06	3.37	12.01
T ₅ - CCC (100 ppm)	426.3	7.40	3.47	12.80
T ₆ - KCl (100 ppm)	405.9	7.05	3.38	12.24
T ₇ - Ascorbic acid (20 ppm)	431.4	7.49	3.49	13.09
T ₈ - Cobalt nitrate (1000 ppm)	413.0	7.17	3.40	12.59
T ₉ - Sodium molybdate (100 ppm)	407.7	7.08	3.38	12.21
T ₁₀ - Mixtalol (10 ppm)	415.1	7.21	3.42	13.07
T ₁₁ - MgSO ₄ (0.5%)	463.2	8.05	3.60	13.02
T ₁₂ - CCC (500 ppm)	472.3	8.20	3.64	13.17
T ₁₃ - NAA (20 ppm)	523.5	9.09	3.82	13.13
T ₁₄ - NAA (40 ppm)	538.0	9.34	3.86	13.25
T ₁₅ - Triacntanol (20 ppm)	516.3	8.97	3.78	12.70
T ₁₆ - Miraculan (2.0 ml/l)	565.2	9.82	3.89	14.37
T ₁₇ - Cytozyme (2.0 ml/l)	524.9	9.12	3.81	12.74
T ₁₈ - APSA (1.0 ml/l)	399.8	6.94	3.35	11.89
T ₁₉ - APSA (2.0 ml/l)	406.9	7.07	3.39	12.11
T ₂₀ - Control	380.0	6.60	3.17	12.30
Mean	448.4	7.79	3.53	12.80
SEm±	15.51	0.79	0.035	0.28
CD (5%)	44.81	2.29	0.10	0.81

APSA = All Purpose Spray Adjuvant



**T₁₃ - Foliar application of NAA (20 ppm)
at flowering and fruit set**



**T₁₄ - Foliar application of NAA (40 ppm)
at flowering and fruit set**



**T₁₅ - Foliar application of Triaccontanol (20 ppm)
at flowering and fruit set**



**T₁₆ - Foliar application of Miraculan (2.0 ml/l)
at flowering and fruit set**

Plate 5a. Influence of foliar application of plant growth regulators on growth and development in pigeonpea

higher 100 seed weight (7.58 g) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, all these treatments were at par with each other. The lower 100 seed weight (6.60 g) was recorded in control.

During second year (2005-06), the treatment with miraculan (2.0 ml/l) recorded maximum 100 - seed weight of 10.56 gram followed by NAA (40 ppm), cytozyme (2.0 ml/l), NAA (20 ppm) and triacontanol (20 ppm). Among seed hardening treatments, CaCl_2 (2 %) registered higher 100 - seed weight (8.15 g) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, all these treatments were on par with each other. The lower 100 - seed weight (7.10 g) was recorded in control.

4.4.7 Number of seeds per pod

The data pertaining to number of seeds per pod as influenced by plant growth regulators and agrochemicals indicated significant increase over control during both the years (Table 43 and 44).

During first year (2004-05), the treatment with miraculan (2.0 ml/l) recorded higher number of seeds per pod (3.89) followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l). Among the seed hardening chemicals, the treatment with CaCl_2 (2 %) registered higher number of seeds per pod (3.50) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, all these treatments were on par with each other. The lower number of seeds per pod (3.17) was observed in control.

During second year (2005-06), the treatment with miraculan (2.0 ml/l) recorded maximum number of seeds per pod (4.24) followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l). Among seed hardening chemicals, the treatment with CaCl_2 (2 %) registered more number of seeds per pod (3.81) followed by ascorbic acid (20 ppm), CCC (100 ppm) and MgSO_4 (100 ppm). However, all these treatments were on par with each other. The lower number of seeds per pod (3.45) was obtained in control.

4.4.8 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 during both the years (Table 43 and 44).

During 2004-05, the treatment with miraculan (2.0 ml/l) registered higher harvest index of 14.72 followed by NAA (40 ppm), MgSO_4 (0.5%), NAA (20 ppm) and CCC (500 ppm). Among the seed hardening chemicals, CaCl_2 (2 %) recorded higher harvest index of 14.07 followed by ascorbic acid (20 ppm), MgSO_4 (100 ppm) and ZnSO_4 (100 ppm). However, these were on par with each other. The lower harvest index of 12.90 was recorded in control.

During 2005-06, the treatment with miraculan (2.0 ml/l) recorded higher harvest index of 14.37 followed by NAA (40 ppm), CCC (500 ppm), NAA (20 ppm) and MgSO_4 (0.5%). Among the seed hardening treatments, CaCl_2 (2 %) recorded higher harvest index of 13.73 followed by ascorbic acid (20 ppm), ZnSO_4 (100 ppm) and CCC (100 ppm). However, these were on par with each other. The lower harvest index of 12.30 was obtained in control.

4.5 CORRELATION STUDIES

The correlation coefficient (r) values were calculated among various morpho-physiological, growth parameters, biochemical attributes and yield and yield components during both the years (2004-05 and 2005-06).



**T₁₇ - Foliar application of Cytozyme (2.0 ml/l)
at flowering and fruit set**



**T₁₈ - Foliar application of APSA (1.0 ml/l)
at flowering and fruit set**



**T₁₉ - Foliar application of APSA (2.0 ml/l) at
flowering and fruit set**



T₂₀ - Control

Plate 5b. Influence of foliar application of plant growth regulators on growth and development in pigeonpea

Table 45 . Correlation co-efficient of grain yield with morphological characters and dry weight in pigeonpea (2004-05)

Characters	1	2	3	4	5	6	7	8	9	10
Seed yield	1.000	0.629**	0.820**	0.886**	0.941**	0.941**	0.940**	0.941**	0.941**	0.941**
Plant height		1.000	0.701**	0.752**	0.666**	0.666**	0.666**	0.665**	0.666**	0.665**
Plant spread (90 DAS)			1.000	0.905**	0.858**	0.857**	0.847**	0.858**	0.857**	0.857**
Plant spread (120 DAS)				1.000	0.914**	0.914**	0.910**	0.914**	0.914**	0.914**
Leaf dry weight (120 DAS)					1.000	1.000**	0.998**	0.997**	0.998**	0.998**
Leaf dry weight (Harvest)						1.000	0.998**	0.999**	0.998**	0.998**
Total dry weight (45 DAS)							1.000	0.998**	0.998**	0.998**
Total dry weight (90 DAS)								1.000	0.997**	0.999**
Total dry weight (120 DAS)									1.000	0.999**
Total dry weight (Harvest)										1.000

DAS: Days after sowing

Table 46. Correlation co-efficient of grain yield with morphological characters and dry weight in pigeonpea (2005-06)

Characters	1	2	3	4	5	6	7	8	9	10
Seed yield	1.000	0.741**	0.817**	0.885**	0.925**	0.925**	0.922**	0.925**	0.925**	0.925**
Plant height		1.000	0.796**	0.841**	0.817**	0.817**	0.813**	0.817**	0.817**	0.817**
Plant spread (90 DAS)			1.000	0.904**	0.857**	0.856**	0.846**	0.857**	0.857**	0.857**
Plant spread (120 DAS)				1.000	0.915**	0.914**	0.911**	0.914**	0.915**	0.915**
Leaf dry weight (120 DAS)					1.000	0.999**	0.998**	0.997**	0.998**	0.998**
Leaf dry weight (Harvest)						1.000	0.999**	0.998**	0.999**	0.998**
Total dry weight (45 DAS)							1.000	0.998**	0.998**	0.998**
Total dry weight (90 DAS)								1.000	0.999**	0.999**
Total dry weight (120 DAS)									1.000	0.999**
Total dry weight (Harvest)										1.000

DAS: Days after sowing

Table 47. Correlation co-efficient of grain yield with growth parameters in pigeonpea (2004-05)

Characters	1	2	3	4	5	6	7	8	9	10
Seed yield	1.000	0.938**	0.952**	0.940**	0.941**	0.941**	0.835**	0.906**	0.120	0.689**
Leaf area index (90 DAS)		1.000	0.987**	0.987**	0.987**	0.987**	0.851**	0.834**	0.084	0.610**
Leaf area index (120 DAS)			1.000	0.980**	0.980**	0.980**	0.862**	0.860**	0.088	0.678**
Absolute growth rate				1.000	0.984**	0.984**	0.902**	0.861**	0.103	0.632**
Crop growth rate (45-90 DAS)					1.000	0.998**	0.900**	0.864**	0.098	0.628**
Crop growth rate (90-120 DAS)						1.000	0.901**	0.864**	0.098	0.627**
Relative growth rate (45-90 DAS)							1.000	0.745**	0.139	0.620**
Relative growth rate (90-120 DAS)								1.000	0.097	0.631**
Net assimilation rate (90 DAS)									1.000	0.247
Net assimilation rate (120 DAS)										1.000

DAS: Days after sowing

Table 48. Correlation co-efficient of grain yield with growth parameters in pigeonpea (2005-06)

Characters	1	2	3	4	5	6	7	8	9	10
Seed yield	1.000	0.926**	0.943**	0.927**	0.925**	0.925**	0.911**	0.911**	0.861**	0.715**
Leaf area index (90 DAS)		1.000	0.987**	0.987**	0.987**	0.987**	0.965**	0.962**	0.786**	0.702**
Leaf area index (120 DAS)			1.000	0.980**	0.980**	0.980**	0.970**	0.963**	0.830**	0.735**
Absolute growth rate				1.000	0.998**	0.999**	0.957**	0.954**	0.811**	0.720**
Crop growth rate (45-90 DAS)					1.000	0.998**	0.958**	0.956**	0.812**	0.727**
Crop growth rate (90-120 DAS)						1.000	0.957**	0.955**	0.811**	0.723**
Relative growth rate (45-90 DAS)							1.000	0.966**	0.814	0.747**
Relative growth rate (90-120 DAS)								1.000	0.836**	0.748**
Net assimilation rate (90 DAS)									1.000	0.780**
Net assimilation rate (120 DAS)										1.000

DAS: Days after sowing

Table 49. Correlation co-efficient of grain yield with growth parameters in pigeonpea (2004-05)

Characters	1	2	3	4	5	6	7	8	9	10
Seed yield	1.000	-0.945**	0.933**	0.930**	0.942**	0.942**	0.941**	0.941**	0.941**	0.941**
Specific leaf weight (120 DAS)		1.000	-0.999**	-0.961**	-0.935**	-0.937**	-0.935**	-0.941**	-0.941**	-0.941**
Specific leaf area (120 DAS)			1.000	0.952**	0.921**	0.924**	0.921**	0.928**	0.928	0.928**
Leaf area ratio (90 DAS)				1.000	0.965**	0.968**	0.966**	0.971**	0.971**	0.971**
Leaf area duration (45 DAS)					1.000	0.999**	0.998**	0.999**	0.999**	0.999**
Leaf area duration (90 DAS)						1.000	0.997**	0.998**	0.998**	0.999**
Leaf area duration (120 DAS)							1.000	0.998**	0.998**	0.999**
Biomass duration (45 DAS)								1.000	0.998**	0.999**
Biomass duration (90 DAS)									1.000	0.999**
Biomass duration (120 DAS)										1.000

DAS: Days after sowing

Table 50. Correlation co-efficient of grain yield with growth parameters in pigeonpea (2005-06)

Characters	1	2	3	4	5	6	7	8	9	10
Seed yield	1.000	-0.942**	0.929**	0.921**	0.947**	0.936**	0.949**	0.925**	0.925**	0.925**
Specific leaf weight (120 DAS)		1.000	-0.999**	-0.961**	-0.966**	-0.976**	-0.981**	-0.941**	-0.941**	-0.941**
Specific leaf area (120 DAS)			1.000	0.953**	0.957**	0.970**	0.975**	0.931**	0.931	0.931**
Leaf area ratio (90 DAS)				1.000	0.992**	0.992**	0.982**	0.970**	0.970**	0.971**
Leaf area duration (45 DAS)					1.000	0.998**	0.995**	0.990**	0.990**	0.990**
Leaf area duration (90 DAS)						1.000	0.997**	0.987**	0.987**	0.987**
Leaf area duration (120 DAS)							1.000	0.988**	0.988**	0.988**
Biomass duration (45 DAS)								1.000	0.998**	0.999**
Biomass duration (90 DAS)									1.000	0.999**
Biomass duration (120 DAS)										1.000

DAS: Days after sowing

Table 51. Correlation co-efficient of grain yield with biophysical and biochemical parameters in pigeonpea (2004-05)

Characters	1	2	3	4	5	6	7	8	9
Seed yield	1.000	0. 935**	0.913**	0.758**	0.992**	0.879**	0.908**	0.823**	0.885**
Relative water content (90 DAS)		1.000	0. 916**	0. 796**	0.922**	0.881**	0. 897**	0.835**	0. 907**
Relative water content (120 DAS)			1.000	0.785**	0.890**	0.936**	0.962**	0.902**	0.899**
Chlorophyll content (90 DAS)				1.000	0.726**	0.768**	0.691**	0.834**	0.658**
Chlorophyll content (120 DAS)					1.000	0.859**	0.894**	0.813**	0.879**
Proline content (90 DAS)						1.000	0.924**	0.894**	0.887**
Proline content (120 DAS)							1.000	0.876**	0.939**
Nitrate reductase activity (90 DAS)								1.000	0.796**
Nitrate reductase activity (120 DAS)									1.000

DAS: Days after sowing

Table 52. Correlation co-efficient of grain yield with biophysical and biochemical parameters in pigeonpea (2005-06)

Characters	1	2	3	4	5	6	7	8	9
Seed yield	1.000	0.924**	0.903**	0.756**	0.988**	0.860**	0.899**	0.844**	0.874**
Relative water content (90 DAS)		1.000	0.915**	0.793**	0.921**	0.860**	0.893**	0.827**	0.908**
Relative water content (120 DAS)			1.000	0.781**	0.891**	0.898**	0.962**	0.905**	0.899**
Chlorophyll content (90 DAS)				1.000	0.727**	0.737**	0.687**	0.828**	0.657**
Chlorophyll content (120 DAS)					1.000	0.832**	0.894**	0.829**	0.876**
Proline content (90 DAS)						1.000	0.882**	0.822**	0.856**
Proline content (120 DAS)							1.000	0.881**	0.937**
Nitrate reductase activity (90 DAS)								1.000	0.799**
Nitrate reductase activity (120 DAS)									1.000

DAS: Days after sowing

Table 53. Correlation co-efficient of grain yield with yield components in pigeonpea (2004-05)

Characters	1	2	3	4	5	6	7
Seed yield	1.000	0.930**	0.980**	0.998**	0.941**	0.941**	0.941**
Number of pods per plant		1.000	0.904**	0.930**	0.994**	0.994**	0.965**
Pod set per cent			1.000	0.980**	0.927**	0.926**	0.947**
Seed yield				1.000	0.941**	0.941**	0.941**
Number of seeds per plant					1.000	0.999**	0.988**
100 seed weight						1.000	0.987**
Number of seeds per pod							1.000

Table 54. Correlation co-efficient of grain yield with yield components in pigeonpea (2005-06)

Characters	1	2	3	4	5	6	7
Seed yield	1.000	0.913**	0.976**	0.998**	0.927**	0.927**	0.925**
Number of pods per plant		1.000	0.958**	0.913**	0.989**	0.988**	0.998**
Pod set per cent			1.000	0.976**	0.963**	0.963**	0.969**
Seed yield				1.000	0.927**	0.927**	0.925**
Number of seeds per plant					1.000	0.663**	0.649**
100 seed weight						1.000	0.987**
Number of seeds per pod							1.000

The correlation of seed yield with various morpho-physiological traits revealed that, seed yield possessed a highly significant positive association with plant height, plant spread, dry weight of leaves and total dry matter (Table 45 and 46) during 2004-05 and 2005-06.

The data pertaining to correlation of seed yield with growth parameters (Table 47, 48, 49 and 50) revealed that, seed yield possessed a significant positive association with LAI, AGR, CGR, RGR, NAR, SLW, SLA, LAR, LAD and BMD during both the years (2004-05 and 2005-06).

The correlation data presented in Table 51 and 52 indicated a significant positive association between seed yield and biochemical and biophysical parameters *viz.*, chlorophyll 'a', chlorophyll 'b', total chlorophyll, NRA, proline content and relative water content.

The correlation of seed yield with yield and yield components *viz.*, number of pods per plant, pod set per cent, number of seeds per plant, seed yield, 100 seed weight and number of seeds per pod was found highly positive and significant correlation during 2004-05 and 2005-06 (Table 53 and 54).

4.6 ECONOMICS

The data on economics of plant growth regulators and seed hardening chemicals is presented in Table 55. The data indicated that, the benefit:cost ratio was higher with miraculan (2.0 ml/l) followed by NAA (20 ppm) and CaCl_2 (2 %).

Table 55. Effect of seed hardening and agrochemicals on benefit:cost ratio in pigeonpea (pooled)

Treatment	Seed yield (q/ha)	Gross return (Rs/ha)	Cost of treatments (Rs)/ha	Total cost of cultivation (Rs/ha)	Benefit: cost ratio
T ₁ - 2%CaCl ₂	19.54	44942	65	12175	3.69
T ₂ - MgSO ₄ (100 ppm)	17.83	41009	65	12175	3.36
T ₃ - ZnSO ₄ (100 ppm)	17.90	41170	80	12190	3.38
T ₄ - 1% KH ₂ PO ₄	16.46	37858	110	12220	3.09
T ₅ - CCC (100 ppm)	18.04	41492	80	12190	3.40
T ₆ - KCl (100 ppm)	16.80	38640	65	12175	3.17
T ₇ - Ascorbic acid (20 ppm)	18.55	42665	65	12175	3.50
T ₈ - Cobalt nitrate (1000 ppm)	17.41	40043	110	12220	3.27
T ₉ - Sodium molybdate (100 ppm)	16.78	38594	65	12175	3.17
T ₁₀ - Mixtalol (10 ppm)	18.16	41768	65	12175	3.43
T ₁₁ - MgSO ₄ (0.5%)	19.07	43861	1300	13410	3.27
T ₁₂ - CCC (500 ppm)	19.48	44804	7500	19610	2.28
T ₁₃ - NAA (20 ppm)	20.40	46920	550	12660	3.71
T ₁₄ - NAA (40 ppm)	20.80	47840	1100	13210	3.62
T ₁₅ - Triacantanol (20 ppm)	19.50	44850	5100	17210	2.60
T ₁₆ - Miraculan (2.0 ml/l)	22.71	52233	780	12890	4.05
T ₁₇ - Cytozyme (2.0 ml/l)	19.71	45333	1260	13370	3.39
T ₁₈ - APSA (1.0 ml/l)	16.20	37260	780	12890	2.89
T ₁₉ - APSA (2.0 ml/l)	16.66	38318	1260	13370	2.86
T ₂₀ - Control	15.86	36478	0.0	12110	--

Cost of chemicals:

Calcium chloride – Rs. 50/kg	Zinc sulphate – Rs. 200/500g	KH ₂ PO ₄ – Rs. 200/500g
CCC – Rs. 350/25g	Ascorbic acid – Rs. 70/5g	KCl – Rs. 150/100g
Cobalt nitrate – Rs. 400/100g	Sodium molybdate – Rs. 200/100g	Mixtalol – Rs. 350/L
Miraculan – Rs. 200/L	Cytozyme – Rs. 400/L	NAA – Rs. 260/25g
MgSO ₄ – Rs. 200/kg	Triacantanol – Rs. 200/g	APSA – Rs. 300/L

Basic cost of cultivation- Rs. 12110/ha

Selling price of pigeonpea – Rs. 2300/q

V. DISCUSSION

Crop growth and yield are the manifestation of morphological, physiological, biochemical and growth parameters. Crop physiology with the aim of understanding the dynamics of yield improvement in crops really began with the work of Balls and Holton in 1915. Later on, several developments took place, of which, the concept of Gregory (1917), Blackmann (1919) and Briggs (1920) in growth analysis provided physiological basis for the events that have occurred during the entire growing period, finally leading to a most complex character i.e. yield.

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 (69 g in 1961 to 30 g in 2002) 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). Pigeonpea is one of the important pulse crops of India which accounts for 90 per cent of the total worlds production, occupying an area of 3.47 m ha with a production of 2.7 m t and the national average yield is 797 kg/ha.

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, since 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.

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.

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. Although, the naturally occurring growth regulators (hormones) normally control plant growth and modification of growth can be achieved by the exogenous application growth regulators. The growth regulators include both growth promoters and retardants, which have been shown to modify the canopy structure and other yield attributes. They are also known to improve the physiological efficiency including photosynthetic ability of plants and offer a significant role in realizing higher crop yields. The PGR's are also known to enhance the source-sink relationship and stimulate the translocation of photoassimilates, thereby increasing the productivity. 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.

With this background, present investigations were carried out to understand the physiological investigations of drought tolerance in pigeonpea by using seed hardening chemicals and PGR's and the results obtained are discussed in this chapter.

5.1 MORPHO-PHYSIOLOGICAL PARAMETERS

The plant growth regulators and agrochemicals significantly influenced the morphological characters viz., plant height, plant spread, days to flowering and days to pod initiation. The values for all parameters were higher during second season (2005-06) due to higher rainfall and better distribution of rainfall during the crop growth period as compared to the first season (2004-05).

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 agrochemicals at 45, 90, 120 DAS and at harvest stage.

Plant height increased from 45 DAS to harvest stage and among the treatments, NAA (40 ppm) recorded significantly higher plant height followed by NAA (20 ppm), miraculan (2.0 ml/l), triacontanol (20 ppm) and cytozyme (2.0 ml/l) at 90 and 120 DAS and lower plant height was found in CCC (500 ppm) and control. The decrease in plant height in CCC (500 ppm) may be attributed to anti - auxin activity of CCC. It blocks the synthesis of IAA in the plant system thereby reducing the plant height. The correlation studies indicated that plant height at harvest had significant correlation with seed yield. This clearly indicates that plant height is one of the important parameters for increasing the yield potential in pigeonpea.

In general, the effect of PGR's was more pronounced as compared to seed hardening with agrochemicals. Ali Khan and Apparao (1969) reported that foliar spray of NAA significantly increased the plant height and stem length and reduced the leaf senescence. Studies conducted with finger millet using CaCl_2 , ascorbic acid, kinetin and benzyl adenine showed greater beneficial effect in terms of germinability and seedling growth under simulated water stress condition or salinity (Krishnasastry *et al.*, 1969). In turmeric application of miraculan and cytozyme increased the plant height and number of leaves (Jirali, 2001). Similar results have also been reported by Arora *et al.*, (1990) in okra.

The plant spread is also one of the important morphological parameters which has been found to increase the yield potential in pigeonpea. In the present study, the plant spread was significantly higher in miraculan (2.0 ml/l) followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) at 90 DAS and at harvest. However, the lower plant spread was noticed in control. The correlation studies also indicated that, there was a positive association between plant spread and seed yield, indicating the importance of this parameter in influencing the seed yield in pigeonpea.

Miraculan contain triacontanol compound which is a straight chain alcohol involved in increasing in the photosynthetic activity and enhancement in the mobilization of photosynthates coupled with rapid increase in reducing sugars, soluble protein, succinate and amino acids (Ganapathi, 2006). It has also been found to increase the activity of 6-phosphogluconate hydrogenase and change the permeability of plant membranes. Increase in the yield potential due to miraculan has been reported in many crops (Jirali, 2001 and Ganapathi, 2006).

Flower initiation is an important phenological stage which determines the plant productivity. The flower initiation was early with CaCl_2 (2.0 %), ZnSO_4 (100 ppm), MgSO_4 (100 ppm), ascorbic acid (20 ppm) and cobalt nitrate (1000 ppm). While, control and cytozyme (2.0 ml/l) showed more number of days for flower initiation. The earliness in flower initiation was due to use of seed hardening chemicals and similar reports were also made by Rabi *et al.*, (1991) in *vicia faba* plants and Bhattacharya and Sharma (2001) in pigeonpea.

Number of days taken for pod initiation was also very less with CaCl_2 (2.0 %), MgSO_4 (0.5%), NAA (20 ppm), NAA (40 ppm) and miraculan (2.0 ml/l) as compared to control. It is inferred that both the phenological stages viz., flower initiation and pod initiation are early due to seed hardening followed by the use of PGR's. Similar reports have also been made by Garai and Datta (2003) in greengram and Varma *et al.*, (2004) in pigeonpea.

5.2 DRY MATTER PRODUCTION AND ITS DISTRIBUTION

Dry matter production is of greater significance in the determination of yield. With the application of plant growth regulators and agro-chemicals, the canopy structure and distribution in leaves can be improved. In the present investigation, the application of PGR's enhanced the accumulation of dry matter.

The dry matter accumulation in leaf increased from 45 to 120 DAS and declined thereafter due to shading and leaf senescence. The treatments showed significant differences among themselves. The leaf dry weight was found to be significantly higher in miraculan (2.0 ml/l), followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm), which suggest that phytohormones play a major role in increasing the leaf dry weight as compared to seed hardening techniques. The lower leaf dry weight was found in control followed by APSA (1.0 ml/l). There was a significant and positive correlation between leaf dry weight and seed yield thereby indicating that leaf dry weight is one of the important parameters, influencing the yield potential in pigeonpea.

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), turmeric (Jirali, 2001) and blackgram (Prabhu 2000).

The amount of total dry matter (TDM) produced is an indication of the overall efficiency of the utilization of resources and better light interception. The data pertaining to total dry weight indicated that it increased substantially from 45 to 120 DAS and a steady increase was found towards harvest. The increase in TDM towards maturity may be due to higher rate of CO₂ fixation and RuBP carboxylase activity during crop growth. The total dry matter differed significantly among the treatments with miraculan (2.0 ml/l) recording significantly higher TDM at all the stages of crop growth followed by NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) and the lower TDM was found in control and APSA (1.0 ml/l). The plant growth regulators were more effective in increasing the TDM as compared to seed hardening treatments. The association of TDM with grain yield was more significant at all the stages of crop growth, thus, 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.

5.3 GROWTH PARAMETERS

The assessment of yield variation in terms of growth and development is very complex, since it involves the effect of external factors on all the physiological processes in plants. It is well established that the infrastructure of the plant is decided by the growth parameters such as leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), specific leaf weight (SLW) and biomass duration (BMD). Growth analysis technique has made substantial contribution to the current understanding of the physiological basis of yield variation in different crops, but the information on pigeonpea is very meagre.

Leaf area fairly gives a good idea of the photosynthetic capacity of the plant. In the present study, the leaf area and LAI increased drastically upto 90 DAS and decreased thereafter towards maturity. In general, the application of plant growth regulators and agrochemicals showed a profound effect on these parameters and significant differences were noticed among the treatments at all the stages during both the seasons. However, growth regulators such as miraculan (2 ml/l), NAA (40 ppm) and NAA (20 ppm) recorded higher leaf area and leaf area index compared to other agrochemicals at all the stages during both the years.

The growth promoting substances such as miraculan, NAA and cytozyme have a positive effect on cell division and cell elongation leading to enhanced leaf expansion. Kalubarme and pandey (1979) also reported that leaf area increased with an increase in time to a maximum coinciding with maximum top growth and steady decline at later stage. Dashora and Jain (1994) also indicated that spraying of triacontanol significantly increased LAI by 27.9 percent in soybean. Deotale *et al* (1994) also found a significant increase in leaf area with the application of miraculan in groundnut and it increased with increase in the dose of triacontanol (0 to 50 ppm). Shindhe and Jadhav (1995) observed higher values for leaf

area due to the foliar application of 20 ppm NAA at flowering in cowpea. Similarly, Gollagi (1999), Prabhu (2000) and Jirali (2001) also reported that in chilli, turmeric and blackgram respectively, the application of miraculan and cytozyme significantly increased leaf area and leaf area index. Maitra *et al* (1998) also noticed that seed hardening with CaCl_2 (2 %) gives significantly higher LAI as compared to control in finger millet. Similarly, Govindan and Thirumurugan (2000) revealed that foliar spray of KCl (1%) or KNO_3 (1%) or in combination, increases the LAI over control in green gram.

According to Watson (1952), crop growth rate is a useful growth parameter for estimating the production efficiency of crop stand and enables to make comparisons between the aspects of study. In the present study, it was found that the absolute growth rate (AGR) and crop growth rate (CGR) increased with increase in the crop duration upto 120 DAS and decreased at harvest, during both the seasons.

In the present study, the PGR's and agrochemicals significantly increased AGR and CGR over the control. The application of miraculan (2.0 ml/l), NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l) significantly increased the AGR and CGR at all the stages. Similarly, Jirali (2001) and Prabhu (2000) reported that the foliar application of miraculan (2000ppm) and cytozyme (2000 ppm) increases AGR and CGR in turmeric and blackgram. Nawalagatti and Panchal (1991) showed that the foliar application of growth regulators viz., vipul (500 ppm) and NAA (20ppm) markedly increases the CGR in groundnut. Prabhakar Reddy (2002) also reported that the growth parameters such as LAI, AGR, CGR and RGR increased significantly with the application of NAA and lihocin in chickpea. Similarly, Bhagat *et al* (1995) noticed that, the foliar application of NAA (40ppm) at flower initiation stage significantly increased the CGR at pod filling stage in blackgram.

Relative growth rate (RGR) represents the increase in dry weight per unit of dry weight already present per unit time. It was found in the present study that RGR declined with an advancement in crop growth, during both the seasons. The decline in RGR with the advancement in crop growth could be due to decline in the rate of dry matter production. The increase in the RGR with plant growth regulators and agrochemicals could be due to the effectiveness of these growth regulators and agrochemicals in increasing not only dry matter production but also the rate of increment in total dry matter. This also could be attributed to increased photosynthetic efficiency by increasing leaf thickness and retaining more chlorophyll content and efficient translocation of photosynthates. Similar results were also noticed by Jirali (2001) in turmeric, Padmavathi (1998) in onion and Prabhu (2000) in blackgram. In general, significantly higher RGR was found in miraculan (2.0 ml/l), NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l). Similarly, Padmavathi (1998) also found that NAA (100 ppm) and miraculan (2000 ppm) results in significantly higher RGR in onion. Similarly, Kamala Thirumalaiswamy and Saktharam Rao (1977) also opined that, seed treatment with 5 ppm CCC and kinetin increase RGR and NAR in pearl millet.

Net assimilation rate (NAR), synonymously called as "unit leaf rate", expresses the rate of increase in dry weight at any instant on a leaf area basis with leaf representing an estimate of the size of the assimilatory area (Gregory, 1926). In general, among the treatments application of plant growth regulators recorded significantly higher NAR compared to agrochemicals at all the stages during both the seasons.

Specific leaf area (SLA) showed significant differences among the treatments at all the stages. It was maximum at 45 DAS and decreased thereafter until harvest during both the seasons. In the present study, SLA showed significantly higher values with miraculan (2.0 ml/l) followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l). The data suggested that the application of growth regulators recorded significantly higher growth parameters (AGR, CGR, LAD, BMD and SLA) followed by agrochemicals and thus helped in increasing the production potential in these treatments. Similarly, Mannikeri (1996) also indicated significant improvement in growth parameters due to the application of growth regulators. Gollagi (1999), Jirali (2001) and Prabhu (2000) also observed significant improvements in growth parameters due to the application of miraculan and cytozyme in turmeric, blackgram and chilli, respectively. Thus, from the data it is clear that the use of growth regulators helps in improving growth parameters and improve yield potential in pigeonpea.

The specific leaf weight (SLW) indicates leaf thickness, which is due to compactness and stacking of mesophyll cells. Since pigeonpea is a C_3 plant, the photosynthetic efficiency

per unit leaf area is low and the increase in leaf thickness could probably be due to enhanced photosynthetic efficiency and more stacking of mesophyll cells. In the present study, the SLW increased from 45 DAS to till harvest during both the seasons. Among all the treatments, growth regulators recorded significantly higher SLW followed by agrochemicals. Similar results were also noticed by Kalubarne and Pandey (1979) in greengram. Shindhe and Jadhav (1995) noticed that foliar application of NAA (20 ppm) at flowering stage gave higher values of SLW in cowpea.

Leaf area ratio (LAR) is the leaf area per unit of plant dry weight and is an indicator of photosynthetic capacity per unit of respiring and growing tissue (Wallace *et al.*, 1972). The LAR was maximum at initial stage and decreased thereafter drastically towards maturity during both the seasons. The LAR differed due to the application of plant growth regulators and agrochemicals. The foliar application of miraculan (2.0 ml/l) followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l) recorded significantly higher LAR compared to control and other agrochemicals. Similarly, Rajamohan (1989) reported that the application of NAA significantly increased LAR in soybean. These results are in conformity with Jirali (2001) and Prabhu (2000), who reported higher LAR with cytozyme (2000 ppm) and miraculan (2000 ppm) in turmeric and blackgram, respectively.

Another parameter that is determined by the LAI of two consecutive growth stages is leaf area duration (LAD), which is an useful parameter, not only for predicting the efficiency of photosynthetic system but also for dry matter production (Chetti and Shirohi, 1995). It indicates the maintenance of assimilatory surface area over a period of time, which is a pre-requisite for the prolonged photosynthetic activity and the ultimate productivity in crop plants. The increase in LAI and LAD could be mainly due to the maintenance of more green leaf area. In the present investigation, LAD increased at increasing rate upto harvest during both the seasons. The foliar spray of miraculan (2.0 ml/l) recorded significantly higher values of LAD followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l) as compared to other agrochemicals. These results are in conformity with Wright *et al* (1983) who observed higher grain yield due to higher LAI and LAD in sorghum. The application of plant growth regulators and agrochemicals also enhanced leaf area duration (LAD) due to their positive influence on leaf development. In general, plant growth regulators recorded significantly higher LAD as compared to other agrochemicals during both the seasons.

Watson (1952) also reported a significant positive correlation between LAD and grain yield in pigeonpea. Similarly, Subbaiah and Shah (1987) indicated that spraying of NAA at vegetative stage recorded more LAD values in groundnut. The foliar application of cytozyme (2000 ppm) and miraculan (2000 ppm) recorded significantly higher LAD values. A similar trend was also reported by Jirali (2001) in turmeric, Padmavathi (1998) in onion, Prabhu (2001) in blackgram and Sai Sankar (2002) in greengram.

Biomass duration (BMD) indicates the maintenance of dry matter over a period of time and is essential for prolonged supply of photosynthates to the developing sink. The biomass duration increased with the age of the crop until harvest. The BMD increased due to the application of plant growth regulators (miraculan, NAA and cytozyme) and other agrochemicals (CaCl_2 , ascorbic acid, CCC and MgSO_4) which could be attributed to increased dry matter production and its maintenance. Application of miraculan (2.0 ml/l) recorded significantly higher BMD followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l) compared to control and other agrochemicals during both the seasons. A significant positive association was observed between biomass duration and grain yield. Similarly, Chougale (1997) also indicated significant differences in biomass duration with the application of growth regulators. Jirali (2001) in turmeric, Padmavathi (1998) in onion, Prabhu (2000) in blackgram and Sai Sankar (2002) in greengram also showed positive association between BMD and yield and the enhancement in BMD with the application of plant growth regulators. The increase in BMD with age due to growth regulator treatments could be mainly attributed to increase in total dry matter, which again depends on the development of leaf area.

5.4 BIOPHYSICAL PARAMETERS

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 RWC was studied. Relative water content (RWC) is a measure of the amount of water present in the leaf tissue in relation to turgid condition and the treatments having higher RWC under drought condition would be preferable to maintain higher water balance. In the present study, the foliar application of miraculan (2.0 ml/l) recorded significantly higher RWC values followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l) compared to control and other agrochemicals during both the seasons. These results are in concurrence with Patil (1987) in sorghum and Amaregouda *et al.*, (1994) in wheat. A high degree of positive association was noticed between RWC and grain yield. This is clearly indicates the significance of RWC in maintaining favourable water balance particularly under rainfed/limited water supply conditions. The increase in RWC 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 RWC.

5.5 BIOCHEMICAL PARAMETERS

In recent years, exciting progress has been made in understanding how endogenous plant hormones control plant development. One of the fundamental question in this area of research is the mechanism by which the presence of plant hormones lead to a changes in plant development.

Identification of substances, which play an important role in osmoregulation is another approach of screening for drought tolerance in crop plants. It is well documented that under drought conditions many osmotically active solutes accumulate in leaves of higher plants which lower the osmotic potential and maintain the turgor of both shoot and roots (Munns *et al.* 1979 and Jones *et al.* 1980). In analogy to this, attempts have been made to find out the influence of exogenously applied synthetic plant growth regulators and also seed hardening chemicals on various plant growth and developmental process in several crops.

Studies indicate that, these minute molecules trigger various physiological processes such as photosynthesis, photorespiration, partitioning of photo - assimilates, mineral ion uptake and nitrogen metabolism, which inturn are linked by numerous interactions leading to productivity (Munns *et al.* 1979 and Jones *et al.* 1980).

From the data it is clear that chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents were maximum at 90 DAS and decreased slightly at 120 DAS of the crop growth, during both the seasons. The effect of plant growth regulators and agrochemicals on total chlorophyll content in leaf exhibited significant differences among them at all the growth stages. Significantly higher chlorophyll content ('a' 'b' and total chlorophyll) was found with growth regulator treatment followed by agrochemicals compared to control.

The variation in chlorophyll content due to growth regulators and agrochemicals may be attributed to decreased chlorophyll degradation and increased chlorophyll synthesis. These results are in accordance with Jayakumar and Thangaraj (1998), who explained that the application of cycocel to groundnut resulted in higher chlorophyll content without the modification of leaf anatomy and decreased chlorophyll degradation. The delay in leaf senescence could also be attributed to higher chlorophyll content. Similarly, Shindhe and Jadhav (1995) reported that the foliar application of NAA (40 ppm) significantly increased the chlorophyll content in cowpea. Dashora and Jain (1994) also found that foliar application of triacontanol increased the chlorophyll content of soybean leaves. It has also been suggested that the application of growth regulators increased the availability of assimilates which inturn resulted in prolonged chlorophyll synthesis (Stoddart 1965). Similarly, Jirali (2001) and Prabhu (2000) and Padmavathi (1998) also recorded significantly higher total chlorophyll content with miraculan and cytozyme at 2000 ppm each respectively in turmeric, blackgram and onion. In the present investigation, the chlorophyll content showed a positive correlation with grain yield indicating its importance in yield determination.

Nitrate reductase is a key enzyme in nitrogen metabolism and is known to be regulated by various environmental factors, apart from its own substrate i.e. nitrate. The

reduction of nitrate to nitrite, catalyzed by nitrate reductase enzyme is the rate limiting step for the utilization of nitrogen in the form of nitrate (Beevers and Hageman 1969). The loss of NR activity in response to water stress is well established (Anikiev and kuramegomedov, 1975). The most widely accepted explanation for the reduction of NR activity during water deficit would seem to be the inactivation of the enzyme, reduction in the availability of nitrate, inhibition of protein synthesis consequent upon the reduction in polyribosomal level, reduction in the availability of NADH through the effect on photosynthesis, respiration and changes in redox potential.

The status of NR is an important determinant of growth parameter during drought. The present study also indicated that NRA increased significantly due to the application of plant growth regulators and seed hardening treatments. Among the treatments, plant growth regulators recorded maximum NRA followed by agrochemicals. It was found to be maximum at 90 DAS and decreased further at 120 DAS during both the seasons. The treatment NAA (40 ppm) recorded maximum nitrate reductase activity followed by miraculan (2.0 ml/l), triacontanol (20 ppm), NAA (20ppm) and cytozyme (2.0 ml/l). These results are in accordance with Gollagi (1999), Prabhu (2000) and Jirali (2001) who reported higher nitrate reductase activity with cytozyme and miraculan in chilli, turmeric and blackgram, respectively. This clearly showed that growth regulators have profound influence on biochemical parameters.

According to Muthuchelian *et al.*, (1994), the foliar spray of triacontanol significantly increased the NRA in *Erythrina karegate* seedlings. Similarly, Sivakumar *et al.*, (2002) revealed that foliar spray of growth regulators such as brassinolid (0.1ppm) and triacontanol (10ppm) lead higher NRA in pearl millet. Prabhakar Reddy (2002) also showed higher NRA activity with NAA, lihocin and cycocel over other treatments in chickpea. From the correlation studies, it is revealed that there is a positive association between nitrate reductase activity and grain yield in pigeonpea.

Free proline content has been shown to accumulate upon desiccation in leaves of many plant species. It has been suggested by Jones *et al.*, (1980) that proline accumulation could make useful contribution to the osmotic adjustment. Blum and Ebercon (1976) indicated that proline plays an important role as storage compound for carbon and nitrogen, detoxification of NH_3 , preserving the hydration of proteins in dehydrated tissues, thereby contributing to the survival of cellular functions.

In the present study, it is clear from the data that plant growth regulators recorded maximum proline content compared to seed hardening treatments both at 90 and 120 DAS during both the seasons. The treatment with miraculan (2.0 ml/l) recorded significantly higher proline content followed by NAA (40 ppm), NAA (20 ppm) and cytozyme (2.0 ml/l) as compared to control and seed hardening treatments both at 90 and 120 DAS during both the seasons. These results are in accordance with Patil (1987) in sorghum and Amaregouda *et al.*, (1994) in wheat. Further a strong positive association between proline content and grain yield was noticed in the present investigation thereby signifying the role of proline in yield determination particularly under rainfed situations.

5.5 YIELD AND YIELD COMPONENTS

Grain yield is the manifestation of morphological, physiological, biochemical, biophysical and growth parameters. Improvement in yield according to Humphries (1979) could happen in two ways i.e., by adopting the existing varieties to grow better in their environment or by altering the relative proportion of different plant parts so as to increase the yield of economically important parts. 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, higher NAR, CGR, BMD and enhanced chlorophyll content, nitrate reductase activity and proline content.

In the present investigation, it is observed that the number of pods per plant, pod set percent, seed yield, number of seeds per plant, number of seeds per pod, 100 - seed weight both on plant and area basis increased due to growth regulator treatments viz. miraculan, NAA and cytozyme and seed hardening treatments viz., CaCl_2 , ascorbic acid, CCC and

MgSO₄. The increase in seed yield could be attributed to significant enhancement in the growth parameter viz., CGR, SLA, LAD, and BMD in addition to harvest index.

The present study also revealed that increase in seed yield was significantly higher in miraculan (2.0 ml/l) followed by NAA (40 ppm). 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. The enzymes associated with chlorophyll metabolism are catalase and peroxidase, which contain iron as the prosthetic group (Agarwal *et al.*, 1983). The plant growth substances, either as spray or seed treatment brings about spectacular results both in yield and quality of vegetable crops (Rieas and Houtz, 1983). Miraculan was found to be significantly superior compared to other treatments in enhancing the plant height, plant spread, days to flowering, days to pod initiation, number of seeds per plant, 100 - seed weight, seed yield. While, the respective characters were recorded minimum in control. The increase in the vegetative characters may be due to enhanced cell division and quick cell multiplication, while the higher yield may be due to better carbon assimilation, better accumulation of carbohydrates and reduced respiration in plants. These results are in agreement with the findings of Mahabir singh and Rajodia (1989) in soybean, Singh and Dohare (1964) and Das and Prusty (1982). 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.

In addition, the present study also indicated that seed hardening with CaCl₂, ascorbic acid, CCC and MgSO₄ significantly increased the number of pods per plant, seed yield per plant, 100 - seed weight and harvest index, which are most important yield determining components in pigeonpea. 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 conformity with the findings of earlier research workers that pre-sowing seed hardening with cycocel (50 mg/l) recorded significantly higher yield per plant in okra (Mehrotra *et al.*, 1970). Seed hardening with CaCl₂ (1%) also recorded significantly higher number of pods per plant and pod yield in groundnut (Arjunan and Srinivasan, 1989).

Increase in the yield of pigeonpea due to foliar spray of triacontanol (0.5 ml/l) has been reported (Patil and Bangal 1985). Masood Ali (1985) also indicated that foliar spray of KCl (2 %) solution significantly increases grain yield in chickpea. Similarly, Goswami and Garg (1985) noticed increased fodder yield by 42 to 50 per cent in lucerne by the application of ascorbic acid. Sen and Misra (1987) reported that treating wheat seeds with CaCl₂ (0.25 %) or KCl (2.5 %) increases the grain yield in wheat compared to control. Similarly, Patil (1987) opined that seed treatment with CaCl₂ (2 %) for four hours increases drought resistance in addition to increasing grain yield by 10 per cent over control in sorghum under dry land condition.

In another study, Jain *et al.*, (1987) reported significantly higher number of pods and yield per plant in soybean due to foliar application of triacontanol (0.1 ppm). Rana and Vashista (1988) reported an increase in tuber weight per plant with the foliar application of miraculan or cytozyme at 100 ml/ha in potato. Shindhe *et al.*, (1991) opined that foliar spray of NAA and KNO₃ increased pod yield in cowpea. Singh *et al.*, (1991) found that foliar spray of cycocel, mixtalol and triacontanol effectively enhanced seed yield in chickpea.

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 CaCl₂ (2 %) gave higher yield in wheat. Puste and Kundu (1995) observed that foliar spray of triacontanol (5 ml/l) increases tuber yield in potato. Chougale (1997) showed that, miraculan and cytozyme are known to effect various physiological traits and increased yield potential of sesamum. Similarly, Jirali (2001) in turmeric Padmavathi (1998) in onion and Prabhu (2000) in blackgram recorded significantly higher yield and yield attributes due to cytozyme and miraculan. The cytozyme contains nitrogen, which enhances cell multiplication and cell elongation and is known to improve the N – fixing bacteria in the soil and ultimately resulting in higher yield (Jones, 1977). Whereas, 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).

Based on the above results, it is inferred that the yield potential in pigeonpea can be improved by using plant growth regulators and agrochemicals. The results also indicated a significant improvement in morpho-physiological traits, growth parameters, biochemical constituents and yield and yield components due to the application of PGR's and agrochemicals. Among the plant growth regulators, foliar application of miraculan (2.0 ml/l) was very effective; while among agrochemicals, CaCl_2 (2 %) was found to be superior over other agrochemicals.

5.6 FUTURE LINE OF WORK

From the present investigation, based on the results obtained the following future line of work is suggested.

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. Little is known about the 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.
5. It is necessary to understand the changes in the genetic make up of the plant due to agrochemicals.

VI. SUMMARY

A field study was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif* seasons of 2004-05 and 2005-06 to study the influence of plant growth regulators and agrochemicals on various morpho-physiological, biochemical and yield and yield components in pigeonpea. The experiment consisted of 20 treatments, laid out in randomized block design with three replications. The results obtained from the present investigation are summarized in this chapter.

1. It was observed in general that the performance of the crop with respect to morpho – physiological, growth parameters, biochemical attributes and yield and yield components were better during *kharif* 2005-06 as compared to *kharif* 2004-05 due to variation in the quantum and distribution of rainfall during the crop growth period.
2. Significant differences were observed in morphological characters *viz.*, plant height, plant spread, days to flowering and days to pod initiation due to the application of plant growth regulators and seed hardening chemicals during both the years (2004-05 and 2005-06). Plant growth regulators (PGR's) recorded significantly higher values as compared to seed hardening chemicals at all the stages. Among, all the treatments miraculan (2.0 ml/l), NAA (40 ppm), NAA (20 ppm), cytozyme (2.0 ml/l) and triacontanol (20 ppm) were found to be more effective in enhancing morphological characters compared to other agrochemicals including seed hardening treatments.
3. Dry matter accumulation in leaves differed significantly between the treatments at all the stages. Among the treatments, significantly higher leaf dry weight was recorded with the application miraculan (2.0 ml/l) followed by NAA (40 ppm) and NAA (20 ppm) over other treatments during both the years.
4. Total dry weight increased due to the application of plant growth regulators and seed hardening chemicals. Among the treatments, miraculan (2.0 ml/l) followed by NAA (40 ppm) and NAA (20 ppm) were found to be more effective during both the years at all the stages.
5. The leaf area and leaf area index increased drastically upto 90 DAS and decreased steadily towards harvest. The application of plant growth regulators and seed hardening chemicals increased the leaf area and leaf area index and the effect was more pronounced with growth regulators. The higher leaf area and leaf area index was recorded with miraculan (2.0 ml/l) followed by NAA (40 ppm) and NAA (20 ppm) over other treatments during both the years.
6. Significantly higher AGR, CGR and RGR were recorded with the application of miraculan (2.0 ml/l) followed by NAA (40 ppm) and NAA (20 ppm) as compared to other treatments.
7. The SLW and LAR differed significantly due to the application of plant growth regulators and seed hardening chemicals. Among the treatments, all these parameters were significantly higher during first year (2004-05) compared to second year (2005-06). Further, these parameters were significantly higher with the application miraculan (2.0 ml/l) followed by NAA (40 ppm) and NAA (20 ppm) compared to other treatments.
8. LAD and BMD showed significant differences between the treatments at all the stages. and increased from 45 DAS to harvest. Among the treatments, foliar application miraculan (2.0 ml/l) followed by NAA (40 ppm) and NAA (20 ppm) were found to be more effective compared to control and other treatments during both the years.
9. Various biophysical and biochemical parameters studied indicated significant differences due to plant growth regulators and seed hardening chemicals. Relative water content, chlorophyll 'a', chlorophyll 'b', total chlorophyll content, nitrate reductase activity and proline content were significantly higher with the application plant growth regulators compared to seed hardening chemicals during both the years.
10. Yield components *viz.*, number of pods per plant, number of seeds per pod, number of seeds per plant, pod set per cent, 100 seed weight and seed yield differed significantly due to the application of plant growth regulators and seed hardening

chemicals at all the stages during both the years. Among the treatments, the effect was more pronounced with the application of miraculan (2.0 ml/l) followed by NAA (40 ppm) and NAA (20 ppm) over other treatments.

11. Based on the above results it is concluded 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.
12. The benefit:cost ratio indicated that it was higher with the application of miraculan (2.0 ml/l) followed by NAA (20 ppm) and CaCl_2 (2%).

VII. REFERENCES

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PHYSIOLOGICAL INVESTIGATIONS ON DROUGHT TOLERANCE IN PIGEONPEA (*Cajanus cajan* L.)

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ABSTRACT

Field experiments were conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during kharif 2004-05 and 2005-06 to study the influence of plant growth regulators and nutrients on various morpho-physiological, biochemical and yield and yield components in pigeonpea. The experiment was laid out in randomized block design twenty treatments and three replications.

The morphological parameters viz., plant height, plant spread and days to flower initiation were significantly higher with the application of miraculan (2.0 ml/l) followed by NAA (40 ppm), NAA (20 ppm) and CaCl_2 (2%) compared to control. Dry matter accumulation in leaves and total dry matter differed significantly between treatments at all the stages. Among the treatments, significantly higher dry matter accumulation was recorded with the application of miraculan (2.0ml/l) followed by NAA (40 ppm).

Among the growth parameters significantly higher LA, LAI, SLA, LAD and BMD was observed with the application of miraculan (2.0 ml/l) followed by NAA (40 ppm), NAA (20 ppm), CaCl_2 (2%) as compared to control. Yield components viz., number of pods per plant, pod set per cent, number of seeds per plant, 100 – seed weight and seed yield were significantly higher with the application of miraculan (2.0 ml/l) followed by NAA (20 ppm), CaCl_2 (2%) as compared to control.

The various biochemical and biophysical parameters (chlorophyll 'a', chlorophyll 'b', total chlorophyll, NRA, proline and relative water content) were significantly higher with the application of miraculan (2.0 ml/l) followed by NAA (40 ppm), NAA (20 ppm) and CaCl_2 (2%) over other treatments. The benefit: cost ratio was higher with miraculan @ 2.0 ml/l (4.05) followed by NAA @ 20 ppm (3.71) and CaCl_2 @ 2% (3.69).