AVENUES TO IMPROVE THE PRODUCTIVITY POTENTIAL UNDER RECEDING SOIL MOISTURE CONDITION IN CHICKPEA (*Cicer arietinum* L.)

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By

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CERTIFICATE

This is to certify that the thesis entitled "**AVENUES TO IMPROVE THE PRODUCTIVITY POTENTIAL UNDER RECEDING SOIL MOISTURE CONDITION IN CHICKPEA** (*Cicer arietinum* L.)" submitted by **Mr. RAMESHA C. K.** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **CROP PHYSIOLOGY** to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this University under my guidance and supervision, and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

Place : Dharwad
Date : 15-2-2005

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" Gratitude is the most Exquisite Form of Memory "

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(*RAMESHA C. K.*)

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I. INTRODUCTION

Pulse crops play an important role in Indian agriculture and India is the largest producer and consumer of pulses in the world. The pulses are known to improve the physical characteristics of the soil through their tap root system, which open the soil into the deeper strata and their ability to use atmospheric nitrogen through biological nitrogen fixation (BNF), which is economically sound and environmentally acceptable (Anon., 2003).

Pulses occupy an unique position not only in Indian agriculture but also in Indian dietaries. They contain 20 to 25 per cent proteins as against 8.12 per cent in cereals. Proteins are rich in essential amino acids like lysine, which is deficit in cereal proteins, and hence the combination of pulses and cereals in dietaries results in the intake of proteins of higher biological value and at the same time, pulses bring about a formidable solution to the alarming problem of protein scarcity of the world predominantly in a country like India where majority of the population are vegetarian.

Among the pulses, chickpea (*Cicer arietinum* L.) is one of the important pulse crops grown during *rabi* season. On an average it produces 126 Kg protein per hectare and is probably the highest protein yielding legume next to groundnut and soybean. In India chickpea ranks first among legumes in area occupying of 4.8 m ha (27.0 per cent) and with a production of 3.5 million tonnes (38.0 per cent) and productivity level of 720 kg/ha. Similarly in Karnataka, it is grown in an area of 3.7 lakh ha with an annual production of 2.39 lakh million tones with an average productivity of 650 kg/ha (Anon., 2003). The major chickpea growing districts of the state are Bellary, Bidar, Bijapur, Dharwad, Gulbarga and Raichur.

Chickpea is essentially a rainfed or post monsoon winter crop. The average yield in India is very low, which might be due to the cultivation of this crop on residual soil moisture in cool dry season. It is generally grown on conserved soil moisture and the moisture in the profile gradually receeds as the crop grows. As a consequence, plant experiences progressively increasing degree of terminal moisture stress. Thus, soil moisture stress assumes a major limiting factor determining the growth and yield of chickpea in peninsular India. Such situation particularly affects the pod formation, which is critical for determining the yield potential (Verma and Promilakumari, 1978).

Since, moisture stress is one of the abiotic stress, which affects the productivity. Research and management practices aimed at overcoming abiotic stress limitations to increase yield have demonstrated that significant progress can be made. Most of the research work done so far has been on understanding the mechanism underlying productivity, but very little has been done with respect to the possibilities of overcoming stresses or limitations imposed by environmental factors.

There is an urgent need to concentrate the work on how best the productivity potential under rainfed conditions can be enhanced by identifying suitable ameliorative measures to overcome the effect of moisture stress due to which there is a great reduction in the productivity potential. There are certain avenues to improve the productivity potential under receeding soil moisture condition viz., seed hardening technique and foliar sprays of agro-chemicals and alcohols to induce drought tolerance in crop plants. But the study on these aspects in chickpea is very meagre and therefore there is an urgent need to improve the productivity potential of chickpea under receeding soil moisture conditions..

Keeping all these views, the present investigation was undertaken with the following objectives:

1. To study the effect of seed hardening chemicals and foliar sprays on morpho-physiological characters in chickpea.

2. To study the biochemical parameters associated with yield in chickpea

3. To study on yield and yield components in chickpea.

Review of Literature

II. REVIEW OF LITERATURE

Chickpea (*Cicer arietinum* L.) is considered as one of the important grain legume crops because of its high nutritional value. In India, it is extensively cultivated as a winter crop, since it thrives well under receeding soil moisture condition. But the productivity depends largely on the efficient utilization of available soil moisture and the reduction in yield is dramatic under severe water stress.

Few workers have studied the use of seed hardening techniques, foliar sprays of agrochemicals and alcohols in different crops. However, the study in this direction on chickpea is very meagre. Hence, an attempt has been made to survey the available literature pertaining to the increase productivity potential under receeding soil moisture condition by using seed hardening chemicals, foliar sprays of agrochemicals and alcohols in crop plants. In this view, the available literatures are reviewed hereunder and presented in this chapter.

2.1 EFFECT OF SEED HARDENING CHEMICALS AND FOLIAR SPRAYS OF AGRO-CHEMICALS ON GROWTH PARAMETERS

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

Ethanol is an active substrate for heterotrophic organisms. Mer, (1957) observed increased growth of oat mesocotyl seedlings when grown in 5% CO_2. The enhanced growth of mesocotyl was closely correlated with dry matter content. Ethanol and CO_2 prolong the meristematic phase and ethanol could stimulate cell division Mer (1958). The same results were confirmed in unicellular algae (*Chlorella vulgaris*) by Bach and Fellig (1958). Street *et al.,* (1958) reporting that ethanol in culture medium can act as a carbon source for growth of algae and ethanol could cause 75 per cent increase in growth as compared to glucose.

Seed hardening has been reported to induce drought resistance in the plants, such seeds as indicated by its capacity to withstand dehydration and overheating. Other beneficial effects of hardening such as inducing better root growth, higher rate of photosynthesis and larger dry matter accumulation (Henckel, 1964). In wheat pre-sowing seed treatment with 5% cycocel, were considerably shorter in height and markedly dark green. The length of the coleoptile, lengths of first leaf, total shoot length and dry weights of shoots were all reduced. (Appleby *et al.,* 1966).

Abdel Hafeez and Hudson (1967) reported that, in the moist soil, plants from hardened seeds grew better and produced significantly more dry weight than unhardened plants, irrespective of soil fertility and also the seed hardened plants in the least fertile mixture had significantly lower leaf areas than unhardened plants in the more fertile soils. Salim and Todd (1968) adapted pre-sowing seed treatment in wheat and barley and found that seeds are capable of germinating in higher concentration of mannitol. Austin *et al.,* (1969) recorded 51 per cent increase in the length of the carrot embryos in seeds, which were hardened compared to the untreated seed. Studied conducted with finger millet using $CaCl_2$, ascorbic acid, kinetin and benzyladenine shown to have a greater beneficial effects interms of germinability and seedling growth under simulated water conditions or salinity (Krishna Sastry *et al.,* 1969). Similarly, Woodruff (1969) adapted the technique of seed hardening in wheat and found that the plants maintained higher leaf relative water content (RWC) under moisture stress condition as compared to unhardened plants.

Mehrotra *et al.* (1970) observed reduction in the height of the okra plants by application of cycocel either to soil at 3 leaf stage or by soaking the seeds in 100 ppm for 24 hrs and also they found that the flowering was delayed by soaking the seeds with cycocel as compared to soil application in okra. 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.

Rajashekhar *et al.* (1970) reported that in ragi pre-sowing seed hardening increased the root growth by 27.0 per cent than unhardened seeds. Similarly, Sadonzev *et al.* (1970) found that seed soaking with 10 per cent cycocel for 4 hours delayed emergence by 1 to 3 days in winter wheat.

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.

Pre-soaking seed hardening with water increased green matter production, number of green leaves per plant, plant height, root length and seed production in grain sorghum (Corleto *et al.,* 1977). Kamala Thirumalaiswamy and Sakharam Rao (1977) reported that, seed treatment with distilled water, 5 ppm CCC, 10 ppm resistine and 5 ppm Kinetin and different moisture levels slightly increased NAR, RGR and leaf area in pearl millet and irrespective of moisture level the size of the leaf was greatly influenced by cycocel followed by kinetln, resistine.

Singh and Thakur (1979) reported that in soybean the improvement in seed germination percentage to the extent of 49, 43, 71, 44 and 47% by pre-sowing soaking with water, cobalt (0.1, 1.0 ppm), molybdenum (1.0 and 2.0 ppm) respectively, over unsoaked seeds and germination relative index (GRI) to the extent of 108, 67, 26, 92 and 102 respectively, over control. Misra and Dwivedi (1980) found that ragi seeds (*Eleusine coracana*) treated with potassium and distilled water produced distinctly more plant height, enhanced tiller production, green leaf number, leaf area and dry weight of shoot significantly compared with the control. Similarly, in another case Channakeshava (1982) reported that the seed treatment of sorghum (cv CSH 5) with distilled water, glucose and gibberellic acid has shown early growth, increased plant height and dry matter production.

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 concentration of the chemical by 10, 40 and 80 mg/l, the radicle growth was increased considerably. Dighe *et al.* (1983) indicated that, cycocel(500 ppm) applied to wheat cultivars by either seed treatment or foliar spray or soil drenching. (1000 ppm) decreased plant height and delayed flowering and maturation by 4 to 5 days as compared to control

Singh *et al.* (1984) stated that soaking of sorghum seeds in water for 12 hrs overnight hastened the flowering period by 96.83 days as against 100 days for control. These four days of enhancement in flowering can be utilized for solving synchronization problem in case of CSH-5 seed production.

Karivaratharaju and Ramakrishnan (1985) reported that pre-sowing seed hardening of ragi seeds in different chemical solutions increased significantly the germination, tillering, plant height, root growth and dry matter production.

Bhatia and Rathore (1986) studied the effect of seed soaking treatment with distilled water, 5% KH_2PO_4, 0.25% $CaCl_2$, 0.1% cycocel, 2.5% NaCl and saturated solutions of Ca $(OH)_2$ on germination and seedling attributes in wheat. They found that treatment with KH_2PO_4 enhanced the germination and increased the number of seedlings per meter row length. Dry matter accumulation and seedling height was increased by KH_2PO_4 followed by distilled water and both were significantly superior over control. Similarly ,seed treatment with 2% $CaCl_2$ 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 RWC and root : shoot ratio (Patil, 1987).

Mandal and Basu (1987) indicated that pre-sowing seed hardening with water increased the germination by 10%, shoot growth by 8% and root growth by 17% in wheat over the control. Arjunan and Srinivasan (1989) indicated that seed hardening treatment of groundnut with $CaCl_2$ (1%) has given significantly higher pod yield through increased germination per cent and higher dry matter accumulation. Eshanna and Kulkarni (1990) revealed that seed treatment with CaCl2 in the ratio of 1:3 (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 10^{-5} M GA_3, kinetin or IAA or 10^{-4} cycocel generally increased number of leaves per plant, root, stem and total dry weight, RGR, NAR and leaf weight ratios in wheat as compared to control. (Gurudev Singh *et al.,* 1991).

Rabie *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. Similarly, Upadhyay (1994) observed increased in the plant height, number of branches, number of flower bud, number of flowers, vegetative growth and yield in chickpea due to foliar application of both NAA, kinetin (10, 20, 30 ppm) and KNO_3 (100, 200, 300 ppm) over control.

Rangaswamy *et al.* (1993) found that seed hardening with $CaCl_2$ at 0.4% and CCC at 0.2% increased the germination per cent, vigour index and root - shoot ratio in sorghum, pigeonpea, groundnut and cowpea. In another study by Jayarami Reddy *et al.* (1996) reported that foliar spray of NAA (10 ppm) + KNO_3 (0.5%) and NAA (20 ppm) + KNO_3 (0.5%) recorded the maximum dry matter production in pigeonpea as compared to control. Similarly, application of 2% ethanol significantly increased the dry matter production, leaf area, LAI, LAD, NAR and SLA in sorghum genotypes (Pawar, 1996).

Koppar (1997) revealed that foliar spray of methanol at different levels (1-20 per cent) significantly increased the plant height, number of green leaves, LAI, LAD, NAR, SLA, SLW and CGR in wheat. Chetti and Pawar (1997) observed that, the plant height, number of leaves, total dry matter and grain yield increased with an increase in concentration of ethanol up to 30 per cent in sorghum. Salunkhe *et al.* (1998) observed that foliar spray of methanol up to 20 per cent in wheat caused gradual increase in the plant height, number of tillers and total dry weight of the plant.

Abdel-Al (1998) reported that foliar sprays of methanol solutions at 10, 20 and 30 per cent significantly increased the plant height, leaf area, dry weight of growth parts, shoot - root ratio and number of bolls per plant in cotton. Maitra *et al (1998)* studied the effect of seed soaking treatments with agro chemicals (distilled water, 0.25% $CaCl_2$, 100ppm KH_2PO_4 and 100 ppm Na_2HPO_4) on growth and productivity in finger millet. Treatment with 100 ppm Na_2HPO_4 caused remarkable improvement in growth attributes such as plant height, LAI, LAD, CGR and dry matter accumulation at different growth stages

Kumar *et al.* (1999) indicated that effect of enhanced photosynthetic activity was reflected on the total dry matter accumulation in cotton. Further, they reported that the increase in photosynthetic activity was noticed with foliar spray of 20 and 30% methanol in cotton. The results revealed by Patil *et al.* (1999) indicated that the height of groundnut plant, number of branches, leaf area and dry matter production increased with increase in the concentration of methanol up to 20 per cent and decreased at higher concentrations. Govindan and Thirumurugan (2000) revealed that the growth parameters like plant height, LAI and dry matter production in green gram were significantly high with treatments received foliar spray of KNO_3 (1%) or KCl (1%) and their combination.

Saikia *et al.* (2000) observed that application of methanol in nursery tea increased the plant height, stem girth, leaf area, number of leaves, number of laterals, fresh and dry weight of shoots and roots significantly and these values were more conspicuous when methanol (20%) was applied in combination with 1% yellow tea dose (YTD). Punithavathi and Palanisamy (2001) revealed that ragi seeds soaked in one per cent concentration of KCl, $CaCl_2$, prosopis as well as pungam for 12 hr recorded higher germination percentage as well as other seed quality parameters like root length, shoot length, vigour index and dry matter production. Dwivedi *et al.* (2001) observed that application of 20% methanol caused short staturdness by reducing plant height and increased total and effective nodes in soybean.

Annadurai *et al.* (2001) observed that soil application of 168 Kg K_2O/ha or 112 Kg K_2O /ha and foliar spray of 2.5% KCl at 45, 75 and 105 days after planting recorded more dry matter production, LAI and cane yield in sugarcane. Similarly, Pawar *et al* (2003) revealed that seed hardening with 2% $CaCl_2$ recorded significantly higher plant height,total dry matter and grain yield in sunflower as compared to control.

Ombase *et al.* (2003) noticed that foliar sprays of methanol up to 20 per cent concentration increased the plant height, number of branches per plant and number of leaves per plant but decreased at higher methanol concentrations in groundnut.

2.2 EFFECT OF SEED HARDENING CHEMICALS, FOLIAR SPRAYS OF AGRO-CHEMICALS ON BIOCHEMICAL PARAMETERS

Cheema *et al.* (1975) revealed that seed hardening of barley with 0.5 per cent cycocel improved the chlorophyll content to the extent of 5.17 mg/g of leaf tissue, protein content in grains and also the relative leaf water content of the leaf tissue. Das and Sarkar (1981) obtained significant increase in chlorophyll content in rice and wheat with the application of 0.5 per cent KNO_3. Shashidhar *et al.* (1981) reported that groundnut cv RS-218 treated with 1% $CaCl_2$ recorded proline content 17 times more than the control. Pre-sowing seed treatment with 0.25% $CaCl_2$ and soil application of 40 Kg P_2O_5/ha recorded higher grain protein percentage in wheat (Avijit Sen and Misra, 1987). Similarly, the seed treatment with 2% CaCl2 recorded higher RWC and proline content in sorghum (Patil, 1987).

Amaregowda *et al.* (1994) revealed that seed treatment with $CaCl_2$ (2%) in wheat increased free proline content and RWC at both 60 and 80 DAS. This treatment also increased chlorophyll b-content, accumulated maximum K-content, total sugar and reducing sugars in leaves.

The application of methanol (0.25 or 0.5%) to soybean at initial stage of pod filling stage was significantly increased leaf chlorophyll content (Li *et al.,* 1995). Pre-sowing seed hardening with water, NaH_2PO_4, triazole, KCl and cowdung increased chlorophyll content, RWC and proline in rice. (Sheela and Thomos Alexander, 1995). Ghosh and Srivastava (1995) revealed that the foliar spray of *Quercus serrata* seedlings with 5.0 mM KCl resulted in higher level of total chlorophyll, total sugars, soluble protein and nitrate reductase activity in the leaves.

Pawar (1996) revealed that application of ethanol (2%) increased total sugar, nitrate reductase activity, stem and leaf crude protein in sorghum. While, application of methanol up to 20 per cent resulted significant increase in total chlorophyll, total sugars, wax content and nitrate reductase activity in wheat (Koppar, 1997).

The pre-sowing seed hardening treatments with 100 ppm of $CaCl_2$, KNO_3, ascorbic acid, pyridoxine hydrochloride, IAA and GA increased chlorophyll content in *Pennisetum americanum* and *Sorghum bicolor* (Kadiri and Hussaini, 1999). The study conducted by Patil *et al.* (1999) revealed that the yield of protein and oil per hectare was increased significantly due to foliar application of 5 to 25 per cent methanol in groundnut. Foliar application of 20 per cent methanol alone or in combination with 1% yellow tea dose (YTD) significantly increased the soluble sugar content of shoots and starch content of roots in tea (Saikia *et al.,* 2000). Ramesh *et al.,* (2001) noticed during 1998 and 1999 that the foliar spray of 25ppm benzyladenine along with 2% DAP and 1% KCl enhanced leaf chlorophyll a contents (1.10 and 1.14 mg/g fresh weight) chlorophyll b (0.43 and 0.49 mg/g fresh weight) respectively in soybean.

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

Grain yield is 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 a direct influence on grain yield. Investigations made by Appleby *et al.* (1966) revealed increased in test weight and grain yield of wheat with seed treatment with 5% cycocel.

Austin *et al.* (1969) noticed that plants from hardened seeds of carrot gave the mean yields of roots 64.0 tons compared to 59.2 tons per hectare from untreated seed. 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 use of hardened ragi seed, it was found to increase the yield on an average 12% more than the unhardened seeds. Hardened seeds produced 6.8 per cent more straw yield than unhardened and better responded to fertilizers. Application of CCC through soil or by soaking the seeds at 50 mg/l of water resulted in a significantly higher yield per plant in okra. (Mehrotra, 1970). The seed soaking with water increased grain yield by 21 and 12 per cent in the two varieties of sorghum i.e 5-4-1-9 and M-35-1, respectively as compared to the control (Parvatikar *et al.*, 1975).

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 yields by 60 per cent in carrot and in lettuce emergence increased by 9 to 11 per cent and yields by 10 to 12 per cent (Pantielev *et al.*, 1976).

Karnail Singh (1976) reported that, seed cotton yield was increased significantly with application of cycocel @ 80 g.ai/ha at 40 DAS over control. Nayeem and Bapat (1976) conducted experiment on sorghum cv R-16, 36A x PD-3-1-11 and M-35-1. The seeds of sorghum cv. R-16, 36 A x PD-3-1-11 and M-35-1 were soaked in $CaCl_2$ solution (1/40 M) and distilled water for 24 hours and then the seeds were dried for few days in the air and they found that among the treatments, the water soaked seeds produced a yield by 1.0, 44.6 and 3.05 per cent respectively 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. Das and Sarkar (1981) revealed that post-flowering foliar spray with 0.5% KNO_3 solution has given higher yield of both grain and straw in rice and wheat. Seed soaking of wheat in 0.5 per cent cycocel prior to sowing increased the grain yield (De *et al.*, 1982).

The experiment conducted by Dighe *et al.* (1983) revealed that, among the different methods of cycocel treatments, the seed treatment and foliar spray of cycocel in wheat produced higher grain yield than the application of cycocel through soil drenching. Avijit Sen and Misra (1984) indicated that, seed treatment with 0.25% $CaCl_2$ prolonged the grain filling period in wheat by way of early ear head emergence and consequently increased the grain yield. Application of foliar spray of potassium K_2SO_4 (1%) and KCl (1%) increased the seed yield by 21.2 and 3.4 per cent respectively over control in black gram (Chandrababu *et al.*, 1985). Similarly, Masood Ali (1985) observed that foliar spray of 2% KCl solution at flowering stage significantly increased grain yield over control in chickpea.

Avijit Sen and Misra (1987) reported that treating wheat seeds with 0.25% $CaCl_2$ or 2.5% KCl increased the grain yield compared to control. While, pre-sowing seed treatment with water in wheat significantly increased the grain yield as compared to control. (Mandal and Basu, 1987). Similarly, Patil (1987) opined that seed treatment with 2% $CaCl_2$ for 4 hours increased drought resistance in sorghum and also increased the grain yield by 10% over control under dry land conditions

Arjunan and Srinivasan (1989) noticed that seed hardening treatment of groundnut with $CaCl_2$ (1%) significantly increased the mean pod yield by 20 per cent over untreated control. Similar results were obtained by seed hardening in bajra (Kannadasan *et al.*, 1985) and in red gram (Karivaratharaju and Ramakrishnan, 1985). 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).

The application of 100 ppm cycocel in okra has increased the yield (17.69 t/ha) as compared to control (8.45 t/ha) in dry land situation (Arora *et al.* 1990).In the same way Patel and Singh (1991) also reported the increased in pod weight of okra with application of 200 ppm cycocel. 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.

Shinde *et al.* (1991) observed that foliar spray of growth regulators (NAA and ethrel) and KNO_3 in cowpea increased the pod yield per plant, weight of individual pod and ultimately resulted in elevating the seed yield by 33%. In another experiment conducted by Sarkar and Bandyopadhyay (1991) revealed that foliar spray of 0.5% KNO_3 at 50% flowering stage obtained higher grain and straw yield in wheat. Upadhyay (1994) recorded foliar application of both NAA, Kinetin (10, 20, 30 ppm) and KNO_3 (100, 200, 300 ppm) at both bud initiation and pod formation stage significantly increases the yield in chickpea. Sarkar and Tripathy (1994) revealed that NO_3 and its counter-ions, both K^+ Ca^{2+}, gave beneficial effects in grain filling and yield of wheat when applied as foliar spray of KNO_3 at 50% flowering stage of the crop.

Nanomura and Benson (1992) revealed that foliar spray of 10 to 30 per cent of methanol increased the growth and development of crops like sorghum, redgram and bengalgram. They also observed an increasing turgidity after several hours of foliar treatment with methanol and also indicated that ethanol or methanol serve as carbon source for plants during the water stress condition.

Balakrishnan *et al.* (1993) reported that foliar spray of KCl (1%) resulted in significantly higher yields than the control in brinjal. Amaregowda *et al.* (1994) observed seed treatment with $CaCl_2$ (2%) had given higher yield by 19 per cent in wheat as compared to control. Seed treatment with cycocel (10 ppm) increased grain yield of bajra by 2.0 tonnes / ha as compared to control (1.82 tonnes / ha). (Bishnoi *et al.*, 1995). The application of methanol at the rate of 0.25 or 0.5 per cent in soybean at the beginning stage of pod filling has increased seed yield significantly due to increase in photosynthetic rate and leaf chlorophyll content (Li *et al.*, 1995).

Christopher Lourduraj *et al.* (1996) revealed that pre-sowing seed hardening of groundnut with $CaCl_2$ (0.5%) recorded the higher pod yield (2033 kg/ha) over control (1822 kg/ha). Jayarami Reddy *et al.* (1996) indiated that foliar spray of 20 ppm NAA + 0.5% KNO_3 recorded maximum seed yield (8.57 q/ha) in pigeonpea over control (7.35 q/ha).

Chetti and Pawar (1997) reported that the sorghum grain yield increased with an increase in the concentration of ethanol. At higher concentrations the difference between any two consecutive concentrations were non-significant. They also indicated that foliar application of ethanol in sorghum genotypes increased the grain yield by 25 to 30 per cent and most economical concentration was 1 to 2 per cent. Koppar (1997) indicated that foliar application of methanol at 4 per cent increased the grain yield by 9 per cent in wheat genotypes.

Keino *et al.* (1997) reported that foliar application of KNO_3 obtained 49 per cent squares in cotton and also indicated that K^+ ions rather than NO_3 is responsible for improving the square development. Similarly, the foliar spray of methanol at 10, 20 and 30 per cent concentrations significantly increased the seed index and seed cotton yield per plant. (Abdel-Al., 1998)

Trehan and Sharma (1998) reported that the foliar spray of 2% KCl at 50 days after planting increased yield by 43 q/ha in potato. Salunkhe *et al.,* (1998) revealed that the grain and straw yields of wheat were increased significantly with increase in the concentration of methanol up to 20 per cent and decreased thereafter. Ebelhar *et al.* (1998) revealed that foliar application of urea and KNO_3 increased lint yield by 5 to 6 per cent (47 and 42 lint/acre) in cotton.

The seed cotton yield was significantly increased due to foliar application of 20 and 30 per cent methanol irrespective of the hybrids. However, the difference in boll weight, fibre length, fineness and bundle strength were not affected significantly with methanol. (Kumar *et al.,* 1999). Patil *et al.* (1999) also revealed that the number of pods per plant, 100 Kernel weight and maximum yield were obtained due to foliar application of 20 per cent methanol in groundnut.

Govindan and Thirumurugan (2000) observed that the foliar spray of 1% KCl + 1% KNO_3 increased the grain yield of green gram by 21.8 per cent over control. Rao *et al.* (2000) conducted the experiment on sorghum during 1996 and 1997 and observed that the application of KCl (1%) at terminal drought stress increased the grain yield by 32 and 27 per cent respectively over control.

Application of methanol at 10 per cent increased the yield by 20 per cent in rainfed cotton (var. Abadhita) and the benefit : cost was 1.7 (Anon., 2000). Similarly, foliar application of 3 % ethanol significantly increased the grain yield in sorghum by 32 per cent (Rao *et al.,* 2000). Foliar application of benzyladinine (25 ppm) along with DAP (2%) and KCl (1%) produced higher grain yield in soybean (Ramesh and Thirumurugan, 2001).

Kalarani *et al.* (2001) reported that the seed treatment of ragi cultivars viz., CO-13, PR 202 and Indaf 9 with combination of 1 per cent KCl and $CaCl_2$ had registered maximum yield of 19.6,17.5 and 13.9 percent respectively over control. Foliar application of methanol at 20 per cent significantly increased the number of pods, pod weight per plant and yield in soybean (Dwivedi *et al.,* 2001).

Ugale and Mungse (2001) revealed that pre-sowing seed hardening of wheat with $CaCl_2$ (2.5 %) produced significantly higher grain yield (4014 kg/ha) over control (3177 Kg/ha). Hallikeri *et al.* (2002) reported that foliar application of 2 per cent urea, 2 per cent DAP and 1 per cent KCl had improved the cotton yield by 19, 5 and 6 per cent respectively over control and further they opined that the response of yield in cotton was more pronounced due to foliar application of 2% urea than the application of 2% DAP or 1 % KCl. Ombase *et al.* (2003) noticed that foliar application of methanol up to 20 per cent applied at 30 and 45 DAS recorded the maximum number of pods per plant, pod yield, kernel yield and haulm yield in groundnut. Dhudhade *et al.* (2003) revealed that foliar spray of 2 or 3% urea produced higher grain yield (1062 kg/ha) as compared to control (698 kg/ha).

Chellaiah *et al.* (2001) revealed that foliar spray of 1% humic acid twice at peak squaring and peak flowering combined with 2% DAP and 1% KCl spray had significantly increased yield of summer irrigated cotton.

Material and Methods

III. MATERIAL AND METHODS

A field experiment was conducted during *rabi,* 2003 to find out the effect of seed hardening treatments (water soaking, $CaCl_2$ and cycocel), and foliar sprays of agro-chemicals *viz.*, major nutrients (KCl and KNO_3) and alcohols (ethanol and methanol) on morpho-physiological, biochemical, yield and yield components in chickpea (*Cicer arietinum* (L.)) at College of Agriculture Farm, University of Agricultural Sciences, Dharwad. The details of materials used and techniques adopted during the course of investigation are briefly described in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was carried out in plot No. 126 of E block on medium black soils of college of Agriculture Farm, University of Agricultural Sciences, Dharwad which is situated at $15^0 12'$ N latitude, $75^0 7'$ E longitude with an altitude of 678 m above mean sea level.

3.2 WEATHER DATA DURING THE CROP GROWTH PERIOD

The meteorological data for 2003-2004 and the mean of previous 53 years were collected from the Meteorological Observatory, college of Agriculture, University of Agricultural Sciences, Dharwad and presented in Table 1.The mean maximum temperature during crop growth period was varied from 32.5^0 C in February -04 to 29.6^0 C in January-04 and the mean minimum temperature ranged from 16.8^0 C in Nov-03 to 14.3^0 C in December-04.The per cent relative humidity during crop growth period was highest in Nov -03 (61%) and lowest during December -03 (51%). The total rainfall during the crop growth period was 1.9 mm.

3.3 SOIL AND ITS CHARACTERISTICS

The experimental site consisted of medium black clay loam soil. Composite soil samples were analysed for their physical and chemical

Table 1: **Monthly meteorological data for the year 2003 – 2004 and average of past 53 years (1950 – 2002) of Main Agricultural Research Station, UAS, Dharwad**

Month	Rainfall (mm)		Relative humidity (%)		Temperature (^{0}C)			
					2003-04		1950-2002	
	2003-04	1950-2002	2003-04	1950-2002	Mean Max	Mean Min	Mean Max	Mean Min
April-03	54.4	48.4	57	77.3	36.5	21.1	37.1	21.3
May-03	0.0	82.9	57	66.9	36.6	21.7	36.5	21.4
June-03	32.3	110.5	75	81.9	30.2	21.4	29.5	21.2
July-03	15.3	148.2	82	87.5	27.2	21.3	27.0	20.9
August-03	8.6	97.0	81	86.6	27.2	20.9	27.0	20.6
September-03	16.1	102.2	79	82.4	27.5	19.9	28.8	20.2
October-03	48.1	132.5	67	76.6	30.8	19.8	30.1	19.3
November-03	1.9	32.6	60	68.3	30.6	16.8	29.4	15.5
December-03	0.0	5.6	51	64.1	29.9	14.3	29.2	13.4
January-04	0.0	0.1	54	63.5	29.6	14.7	29.2	14.1
February-04	0.0	0.0	53	51.2	32.5	16.4	34.6	16.0
March-04	0.0	0.1	49	56.6	36.5	19.6	35.7	18.8
Total	977.3	767.1						

properties as per the procedure of Piper (1950) and Jackson (1967), and the details are furnished in Table 2.

3.4 EXPERIMENTAL DETAILS

3.4.1 Treatment details

The experiment consisted of four seed hardening treatments viz., water soaking, $CaCl_2$ (2%) and cycocel (500 and 1000 ppm), two major nutrients, viz.,KCl (1 and 2%) and KNO_3 (1 and 2%) and two alcohols, ethanol (2 and 4%) and methanol (2 and 4%).

Genotype : Annigeri - 1

Treatments : Thirteen

Replications : Three

T_1 Control

T_2 Water soaking

T_3 Seed hardening with 2% $CaCl_2$

T_4 Seed hardening with cycocel (500 ppm)

T_5 Seed hardening with cycocel (1000 ppm)

T_6 Foliar spray of KCl (1%) at 45 and 65 DAS.

T_7 Foliar spray of KCl (2 %) at 45 and 65 DAS.

T_8 Foliar spray of KNO_3 (1%) at 45 and 65 DAS.

T_9 Foliar spray of KNO_3 (2 %) at 45 and 65 DAS.

T_{10} Foliar spray of ethanol (2 %) at 45 and 65 DAS.

T_{11} Foliar spray of ethanol (4 %) at 45 and 65 DAS.

T_{12} Foliar spray of methanol (2 %) at 45 and 65 DAS.

T_{13} Foliar spray of methanol (4 %) at 45 and 65 DAS.

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

Particulars	Value obtained	Method adopted
A. PHYSICAL PROPERTIES		
Clay (%)	32.70	International pipette method (Piper, 1950)
Silt (%)	9.50	International pipette method (Piper, 1950)
Fine Sand (%)	31.24	International pipette method (Piper, 1950)
Coarse sand (%)	26.56	International pipette method (Piper, 1950)
B. CHEMICAL PROPERTIES		
Total N (Kg ha^{-1})	264.52	Modified Kjeldahl's method (Jackson, 1967).
Available P_2O_5 (Kg ha^{-1})	16.50	Olsen's method (Jackson, 1967)
Available K_2O (Kg ha^{-1})	245.35	Flame photometer (Jackson, 1967)
Soil pH (1:2.5)	6.70	pH meter (Jackson, 1967).
EC (dS m^{-1})	0.43	Jackson (1967)

3.4.2 Design and layout

The experiment was laid out in randomized block design with three replications. The plan of layout of the experiment is given in Fig. 1.

Plot size : Gross plot size : 2.25 m x 3.25 m

Net plot size : 2 m x 3 m

3.5 CULTURAL PRACTICES

3.5.1 Land preparation

After the harvest of the previous crop, the land was ploughed with a disc plough, subsequently the land was harrowed twice and smoothened with wooden plank to prepare a fine seed bed. Small bunds were erected around each plot to avoid movement of fertilizer and surface flow of rain water from one plot to another.

3.5.2 Method of seed hardening treatment

A day before sowing the chickpea seeds were soaked separately in 2% $CaCl_2$ solution,500 and 1000 ppm cycocel and water for two hours and the seeds were dried under shade and used for sowing.

3.5.3 Fertilizer application

The crop was fertilized with nitrogen and phosphorus at the rate of 12.5:25 kg ha-1 in the form of urea and super phosphate respectively. At sowing entire quantity of nitrogen and phosphorous was applied as basal dose and mixed thoroughly into the soil.

3.5.4 Spacing

Inter- row spacing : 30 cm

Intra -row spacing : 10 cm

LEGEND

T_1 : Control

T_2 : Water soaking

T_3 : Seed hardening with 2% $CaCl_2$

T_4 : Seed hardening with cycocel (500 ppm)

T_5 : Seed hardening with cycocel (1000 ppm)

T_6 : Foliar spray of KCl (1%) at 45 and 65 DAS.

T_7 : Foliar spray of KCl (2 %) at 45 and 65 DAS.

T_8 : Foliar spray of KNO_3 (1%) at 45 and 65 DAS.

T_9 : Foliar spray of KNO_3 (2 %) at 45 and 65 DAS.

T_{10} : Foliar spray of ethanol (2 %) at 45 and 65 DAS.

T_{11} : Foliar spray of ethanol (4 %) at 45 and 65 DAS.

T_{12} : Foliar spray of methanol (2 %) at 45 and 65 DAS.

T_{13} : Foliar spray of methanol (4 %) at 45 and 65 DAS.

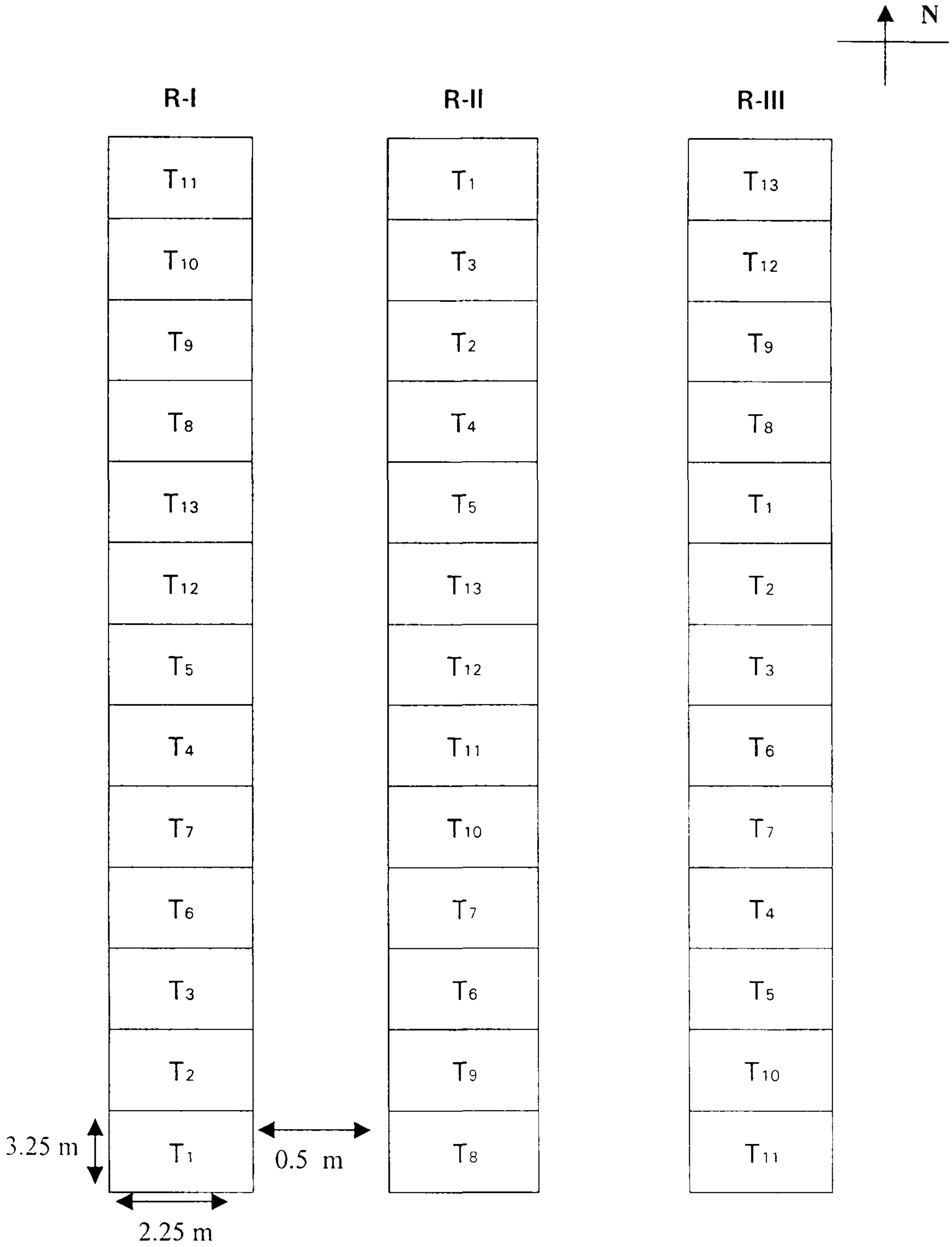

Fig. 1: Plan of layout of the experimental site

3.5.5 Seed source and sowing

Seeds were obtained from Main Research Station,Dharwad. Healthy and bold seeds were dibbled with a spacing of 30 cm x 10 cm to a depth of 5 cm on 5th November 2003. The crop was given protective irrigations as and when required.

3.5.6 Thinning operation

The seedlings were thinned out by maintaining one plant per hill after 15 days of sowing.

3.5.7 Plant protection and interculture operation

Interculture operation was carried out at three weeks after sowing immediately after hand weeding. The crop was sprayed with endosulfan at 2 ml/l in order to control pod borer infestation.

3.5.8 Harvesting

The crop was harvested when plants started drying to pale colour, leaflets started shedding and pods turning to pale colour. The border rows plants were first uprooted manually from all the sides of each plots and then the net plots were harvested excluding five plants randomly selected and tagged plants for recording the observations. The harvested plants were dried in the shade for seven days. The seeds were separated manually by gently beating the dried plants with the wooden stick. The seeds were cleaned and dried in the shade, the seed yield (g plant^{-1}) was recorded for each treatment and then seed yield per hectare was computed and expressed as q ha^{-1}.

3.6 COLLECTION OF EXPERIMENTAL DATA

Five plants were selected randomly from each plot for recording morphological observations at different stages

3.6.1 Morphological characters

3.6.1.1 Plant height

The perpendicular distance form ground level to tip of main stem of tagged plants was measured and the average of five plants was taken and expressed in centimeter (cm).

3.6.1.2 Days to 50 per cent flowering

The number of days taken for 50 per cent of the plants to flower in each plot was recorded.

3.6.1.3 Total dry matter production and its partitioning

Randomly selected five plant samples were separated into leaf, stem and reproductive parts and dried in oven at 80^{0}C until constant weight was obtained. Total dry matter was calculated adding the dry weight of different plant parts and expressed as grams per plant at different intervals of crop growth period.

3.6.2 Growth analysis

3.6.2.1 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)

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

3.6.2.2 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 g m^{-2} day^{-1}.

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

where,

W_1 = Dry weight of the plant (g/m^2) at time t_1

W_2 = Dry weight of the plant (g/m^2) at time t_2

t_1 & t_2 = Time intervals in days.

3.6.2.3 Relative growth rate (RGR)

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

$$RGR = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

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_2-t_1 = Time interval in days.

3.6.2.4 Net assimilation rate (NAR) :

It is the rate of dry weight increase per unit leaf area per unit time (Watson, 1952). It is expressed as g dm^{-2} day^{-1} and calculated as

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e A_2 - Log_e A_1}{A_2 - A_1}$$

where,

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

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

3.6.2.5 Specific leaf weight (SLW)

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

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

3.6.2.6 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 given by Power *et al.* (1967) and expressed in days

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

where,

L_i = Total dry matter at i^{th} stage.

$L_{(i+1)}{}^{th}$ = Total dry matter at $(i+1)^{th}$ stage.

t_1 & t_2 = Time interval between i and $(i+1)^{th}$ stage.

3.6.2.7 Biomass duration (BMD)

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

$$BMD = \frac{TDM_i + TDM_{(i+1)}}{2} \times t_2 - t_1$$

where,

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

$TDM_{(i+1)}{}^{th}$ = Total dry matter at $(i+1)^{th}$ stage.

t_1 & t_2 = Time interval between I and $(i+1)^{th}$ stage .

3.6.2.8 Absolute growth rate (AGR)

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

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

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.

3.6.2.9 Relative water content (RWC)

Relative water content was estimated as per the method of Barrs and Weatherly (1962) at 40, 60, 80 DAS in the experiment. The leaves were separated from the leaflets and weighed accurately in an electric balance. This was taken as fresh weight, the weighed leaves were floated in petridish containing distilled water and allowed to take up water for four hours. After four hours, leaves were taken out and their surface was blotted gently, this was referred as turgid weight. Same leaves after drying at 80°C for 48 hours reweighed for dry weight. The RWC was calculated by using the following formula

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

3.6.3 Yield parameters

3.6.3.1 Number of pods per plant

Total number of pods from the five tagged plants was counted and average pod number per plant was worked out.

3.6.3.2 Shelling percentage

Weight of seeds from 100 pods drawn randomly and shelling percentage was calculated by using the formula

$$SP = \frac{\text{Seed weight (g)}}{\text{Pod weight (g)}} \times 100$$

3.6.3.3 Pod yield per plant

The average weight of total pods in five tagged plants were recorded as pod yield per plant.

3.6.3.4 Seed yield per plant

The dried pods used for recording pod weight per plant were shelled and seed yield were recorded and expressed as seed yield per plant in grams.

3.6.3.5 Hundred seed weight

Hundred seeds were counted from the samples drawn from seed yield of each net plot and the weight of 100 seeds was recorded and expressed in grams.

3.6.3.6 Harvest index

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

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6.3.7 Grain yield per hectare

The plants harvested from the net plot were threshed to obtain grain yield per net plot, which was converted to grain yield in quintals per hectare .

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 polythene 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^{0}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, CL-54) 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^{-1}fresh weight.

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

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

$$\text{Total chlorophyll (mg g}^{-1}\text{ fr.wt.)} = 20.2 \times A_{645} + 8.02 \times A_{663} \times \frac{V}{1000 \times w \times a}$$

where,

A_{645} = Absorbance of the extract at 645 nm

A_{663} = Absorbance of the extract at 663 nm

V = Volume of the extract (20 ml)

w = Fresh weight of the sample (100 mg)

a = path length of cuvette (1 cm)

3.7.2 Estimation of Nitrate reductase activity in leaves

The nitrate reductase activity (NRA) in vivo was estimated at regular intervals following the method of Sardhambal *et al.* (1978). Leaves were cut into small pieces, weighed and suspended in 0.1M KNO_3 under bright light for 1 hour for complete stomatal opening. These pieces were transferred to 25 ml volumetric flasks containing 5ml of stock solution having 0.1M phosphate buffer (pH 7.5), 0.002M KNO_3, propanol (5%) and 2 drops of chloremphenical (0.5mg/ml). The flasks were incubated at 30^{0}C for 30 minutes in dark, and the reaction was stopped by adding 0.1ml of zinc acetate (1.0M) and 1.9ml of ethanol (70%).The contents were centrifuged at 3000 rpm for 10 minutes and the supernatant was collected. To the supernatant, 1.0 ml of sulphanilamide (1%) and 1 ml of 0.02% NNEDA (N-napthyl ethylene diamine dihydrochloride) were added and incubated at room temperature for 20 minutes. The absorbance measured at 520nm in UV-Vis spectrophotometer (Elico, CL-54). The activity of nitrate reductase was determined from a standard curve of KNO_2 and expressed as umoles NO_2 formed per g fresh weight per hour.

3.7.3 Estimation of free proline content

Proline content in the leaf tissue was estimated following method as suggested by Bates *et al.* (1973). The leaf sample of 0.5 g was homogenized in 10 ml of 3 per cent sulphosalicylic acid. The homogenate was filtered through a double layered filter paper. Transferred 2 ml of the filterate to a test tube to which 2 ml of ninhydrin reagent (2.5 g of ninhydrin was dissolved in 40 ml orthophosphoric acid and 60 ml of glacial acetic acid), 2 ml of glacial acetic acid were added. The test tubes containing the mixture were placed in boiling water bath for one hour. The test tube was cooled by keeping in a ice bath. The contents were transferred to a separating funnel and 4 ml of toluene was added and mixed vigorously. The colored toluene fraction was separated and measured at 520 nm in a UV-Vis spectrophotometer (Elico, CL-54). A blank was maintained with all the reactants except the leaf extract. Proline content in leaf tissue was calculated using the formula.

$$\text{Proline content } (\mu g\ g^{-1} \text{ fr.wt.}) = \frac{36.23 \times Od_{520} \times \text{Volume of the aliquot made (ml)}}{\text{Volume of the aliquot (ml)} \times \text{weight of the sample (mg)}}$$

3.8 STATISTICAL ANALYSIS

The data were subjected to analysis of variance by following the method of Panse and Sukhatme (1967). The level of significance used in 'F' and 't' test 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 treatments was worked out on the basis of the present market rates of all the applied inputs during experimentation on per hectare basis

Experimental Results

IV. EXPERIMENTAL RESULTS

A field experiment was conducted during *rabi,* 2003 at College of Agriculture Farm, University of Agricultural Sciences, Dharwad to study the influence of seed hardening techniques, use of growth retardant and chemicals on various morpho-physiological, growth, biochemical and yield parameters in chickpea (var, Annigeri-1). 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 indicated significant differences due to various treatments at all the stages except at 40 DAS. In general, plant height increased from 40 DAS to harvest stage. (Table 3). Among the treatments, seed hardening with 2% $CaCl_2$ recorded significantly higher values over all other treatments. However, it was on par with application of ethanol (4%) and methanol (4%) at 60 DAS. The plant height in the treatments *viz.*, ethanol, methanol, KCl, KNO_3 at both the levels and water soaking treatment were on par with each other at 80 DAS. While, ethanol (2 and 4%), methanol (2 and 4%), KCl (2%) and KNO_3 (2%) at harvest were on par with each other. Significantly lower plant height was observed in the treatment seed hardening with cycocel (1000 ppm) as compared to control. However, the treatments within KCl, KNO_3, ethanol, methanol did not differ significantly. Maximum plant height (47.66cm) was recorded in seed hardening with 2% $CaCl_2$ at harvest.

Table 3. **Influence of seed hardening techniques, use of growth retardant and chemicals on plant height (cm) at different stages in chickpea**

Treatments	Days after sowing			
	40 DAS	60 DAS	80 DAS	At harvest
T1 : Control	25.33	30.83	36.67	40.50
T2 : Water soaking	26.03	34.96	41.20	43.00
T3 : $CaCl_2$ (2%) seed treatment	27.33	38.86	44.00	47.66
T4 : CCC (500 ppm) seed treatment	24.90	29.33	36.73	40.24
T5 : CCC (1000 ppm) seed treatment	23.86	28.62	35.96	39.35
T6: KCl (1%) foliar spray	24.30	34.76	40.93	43.53
T7: KCl (2%) foliar spray	25.70	35.80	41.33	44.13
T8 : KNO_3 (1%) foliar spray	24.86	34.53	41.83	43.77
T9 : KNO_3 (2%) foliar spray	25.10	35.10	42.03	44.63
T10:Ethanol (2%) foliar spray	24.70	35.66	41.73	44.60
T11:Ethanol (4%) foliar spray	25.36	36.80	42.13	45.96
T12:Methanol (2%) foliar spray	24.63	35.20	41.66	44.95
T13: Methanol (4%) foliar spray	25.60	36.23	42.00	45.69
Mean	**25.20**	**34.36**	**40.63**	**43.69**
S.Em ±	0.900	1.05	1.23	1.28
CD @ 5%	NS	3.08	3.61	3.74

4.1.2 Leaf dry weight (g plant^{-1})

The data pertaining to leaf dry weight presented in Table 4 indicated significant differences among the treatments at all the stages except at 40 DAS. In general, the leaf dry weight increased from 40 DAS to 60 DAS and decreased thereafter, Among the treatments seed hardening with 2% $CaCl_2$ recorded significantly higher leaf dry matter followed by seed hardening with cycocel (1000 and 500ppm). Significantly lower leaf dry matter was recorded in control at all the stages. However, it did not differ significantly with water soaking and application of 1% KCl at 60 DAS. While, water soaking and application of nutrients at 80 DAS and 1% KCl at harvest did not differ significantly. Maximum leaf dry weight (2.16 g plant^{-1}) was recorded in seed hardening with 2% $CaCl_2$ at harvest.

4.1.3 Stem dry weight (g plant^{-1})

The stem dry weight increased from 40 to 80 DAS and decreased thereafter at harvest (Table 5). Treatments differed significantly at all the stages except at 40 DAS. Among the treatments seed hardening with 2% $CaCl_2$ recorded significantly higher stem dry weight followed by seed hardening with cycocel (1000 ppm). However, it was on par with ethanol (2 and 4%), methanol (4%), KNO_3 (2%), and KCl (2%) at 60 DAS.The treatments, seed hardening with cycocel (500 ppm) at 80 DAS and at harvest were on par with each other. Lower stem dry weight recorded significantly in control. but it did not differ significantly with the application of 1% KCl at 60 DAS and KCl (1% and 2%) at harvest. Maximum stem dry weight was recorded in seed hardening with 2% $CaCl_2$ (8.08 g plant^{-1}) at harvest.

Table 4. Influence of seed hardening techniques, use of growth retardant and chemicals on leaf dry matter (g $plant^{-1}$) at different stages in chickpea

Treatments	Days after sowing			
	40 DAS	60 DAS	80 DAS	At harvest
T1 : Control	1.08	2.82	2.05	1.48
T2 : Water soaking	1.34	3.37	2.25	1.84
T3 : $CaCl_2$ (2%) seed treatment	1.62	4.67	3.70	2.16
T4 : CCC (500 ppm) seed treatment	1.40	3.93	3.32	2.01
T5 : CCC (1000 ppm) seed treatment	1.51	4.48	3.43	2.11
T6: KCl (1%) foliar spray	0.92	3.45	2.00	1.35
T7: KCl (2%) foliar spray	1.11	3.82	2.42	1.46
T8 : KNO_3 (1%) foliar spray	1.04	4.20	2.28	1.98
T9 : KNO_3 (2%) foliar spray	1.10	4.25	2.29	2.00
T10:Ethanol (2%) foliar spray	1.11	4.37	2.78	1.93
T11:Ethanol (4%) foliar spray	1.17	4.54	3.24	2.06
T12:Methanol (2%) foliar spray	1.00	4.03	2.71	1.84
T13: Methanol (4%) foliar spray	1.10	4.25	2.72	1.93
Mean	**1.19**	**4.025**	**2.78**	**1.86**
S.Em ±	0.14	0.29	0.26	0.10
CD @ 5%	NS	0.85	0.76	0.29

Table 5. Influence of seed hardening techniques, use of growth retardant and chemicals on stem dry weight (g $plant^{-1}$) at different stages in chickpea

Treatments	Days after sowing			
	40 DAS	60 DAS	80 DAS	At harvest
T1 : Control	0.621	2.73	4.22	4.03
T2 : Water soaking	0.852	3.43	5.86	4.91
T3 : $CaCl_2$ (2%) seed treatment	1.037	4.36	8.73	8.08
T4 : CCC (500 ppm) seed treatment	0.875	3.49	7.87	7.11
T5 : CCC (1000 ppm) seed treatment	0.969	4.30	8.28	7.58
T6: KCl (1%) foliar spray	0.643	3.45	4.59	4.12
T7: KCl (2%) foliar spray	0.742	3.90	6.15	4.30
T8 : KNO_3 (1%) foliar spray	0.690	3.74	5.93	5.07
T9 : KNO_3 (2%) foliar spray	0.711	3.80	6.06	5.20
T10:Ethanol (2%) foliar spray	0.627	3.84	6.34	5.94
T11:Ethanol (4%) foliar spray	0.628	3.97	7.57	6.36
T12:Methanol (2%) foliar spray	0.610	3.73	6.37	5.18
T13: Methanol (4%) foliar spray	0.639	3.90	7.26	6.13
Mean	**0.739**	**3.74**	**6.55**	**5.69**
S.Em ±	0.097	0.17	0.22	0.22
CD @ 5%	NS	0.51	0.66	0.66

4.1.4 Dry weight of reproductive parts (g plant^{-1})

Significant differences were observed due to various treatments with respect to dry weight of reproductive parts at all the stages except at 40 DAS (Table 6). The dry weight of reproductive parts was increased from 40 DAS to harvest in all the treatments. Among the treatments seed hardening with $CaCl_2$ (2%) has recorded significantly higher reproductive parts dry weight followed by seed hardening with cycocel (1000 and 500 ppm) as compared to control. Significantly lower dry weight of reproductive parts was recorded in control, but it did not differ significantly with water soaking and application of KCl (1%) at 60 and 80 DAS.

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

The results pertaining to total dry matter indicated significant differences among the treatments at all the stages except at 40 DAS. (Table 7). The total dry matter increased from 40 DAS to harvest in all the treatments. Among the treatments, pre-sowing seed hardening with 2% $CaCl_2$ has recorded significant increase in total dry matter content followed by seed hardening with cycocel (1000 and 500 ppm), ethanol (4%) and methanol (4%) as compared to control. Significantly lower total dry matter was observed in control at all the stages, but, it did not differ significantly with KCl (1%) at 80 DAS and at harvest. Maximum total dry weight (26.82 g plant^{-1}) was recorded in pre-sowing seed hardening with $CaCl_2$ (2%) at harvest.

Table 6. Influence of seed hardening techniques, use of growth retardant and chemicals on reproductive parts dry weight (g plant^{-1}) at different stages in chickpea

Treatments	Days after sowing			
	40 DAS	60 DAS	80 DAS	At harvest
T1 : Control	0.11	0.49	7.44	9.55
T2 : Water soaking	0.12	1.38	8.83	11.70
T3 : $CaCl_2$ (2%) seed treatment	0.14	2.17	14.27	16.57
T4 : CCC (500 ppm) seed treatment	0.13	2.07	13.15	14.28
T5 : CCC (1000 ppm) seed treatment	0.14	2.17	13.34	14.74
T6: KCl (1%) foliar spray	0.12	1.09	8.98	11.63
T7: KCl (2%) foliar spray	0.12	1.27	9.30	12.09
T8 : KNO_3 (1%) foliar spray	0.12	1.25	9.61	12.18
T9 : KNO_3 (2%) foliar spray	0.12	1.38	9.80	12.32
T10:Ethanol (2%) foliar spray	0.11	1.37	9.05	13.77
T11:Ethanol (4%) foliar spray	0.12	1.39	10.71	14.06
T12:Methanol (2%) foliar spray	0.11	1.38	9.665	12.82
T13: Methanol (4%) foliar spray	0.12	1.42	10.28	12.97
Mean	**0.12**	**1.45**	**10.34**	**12.90**
S.Em ±	0.01	0.08	0.61	1.05
CD @ 5%	NS	0.25	1.78	3.06

Table 7. Influence of seed hardening techniques, use of growth retardant and chemicals on total dry matter (g plant^{-1}) at different stages in chickpea

Treatments	Days after sowing			
	40 DAS	60 DAS	80 DAS	At harvest
T1 : Control	1.82	6.05	13.72	15.07
T2 : Water soaking	2.30	8.18	16.94	18.46
T3 : $CaCl_2$ (2%) seed treatment	2.81	11.21	26.70	26.82
T4 : CCC (500 ppm) seed treatment	2.41	9.50	23.56	24.17
T5 : CCC (1000 ppm) seed treatment	2.62	10.96	24.36	25.14
T6: KCl (1%) foliar spray	1.69	8.00	15.57	17.10
T7: KCl (2%) foliar spray	1.97	9.00	17.83	17.86
T8 : KNO_3 (1%) foliar spray	1.86	9.20	18.26	19.22
T9 : KNO_3 (2%) foliar spray	1.94	9.56	18.15	19.82
T10:Ethanol (2%) foliar spray	1.85	9.59	18.17	21.64
T11:Ethanol (4%) foliar spray	1.92	9.90	21.54	22.48
T12:Methanol (2%) foliar spray	1.73	9.15	18.75	19.49
T13: Methanol (4%) foliar spray	1.87	9.57	20.27	21.04
Mean	**2.06**	**9.22**	**19.53**	**20.67**
S.Em ±	0.24	0.38	0.83	0.89
CD @ 5%	NS	1.11	2.42	2.61

4.2 GROWTH PARAMETERS

4.2.1 Leaf area index (LAI)

The data on leaf area index (Table 8) increased from 40 to 60 DAS and decreased thereafter at 80 DAS. All the treatments differed significantly at all the stages except at 40 DAS and among the treatments seed hardening with 2% $CaCl_2$ recorded significantly higher values followed by foliar spray of ethanol (4%) and methanol (4%) compared to other treatments at all the stages. However, significantly lower leaf area index was observed in control, but it did not differ significantly with seed hardening with cycocel (500 ppm) at 60 DAS and similarly, water soaking, seed hardening with cycocel (500 ppm), KCl (1%) and KNO_3 (1%) at 80 DAS.

4.2.2 Crop growth rate (g m^{-2} day^{-1})

The results pertaining to crop growth rate (CGR) indicated significant differences among the treatments at all the stages (Table 9). The crop growth rate increased continuously up to 80 DAS in all the treatments. Among the treatments, the maximum crop growth rate was obtained significantly in seed hardening with 2% $CaCl_2$ followed by seed hardening with cycocel (1000 and 500 ppm), ethanol (4%) and methanol (4%) as compared to control. However, control recorded significantly lower crop growth rate values at all the stages, but it was on par with water soaking, KCl at both the levels and ethanol (1%) at 60-80 DAS. Maximum CGR (25.89 g m^{-2} day^{-1}) was recorded in seed hardening with 2% $CaCl_2$ at 60-80 DAS.

Table 8. **Influence of seed hardening techniques, use of growth retardant and chemicals on leaf area index at different growth stages in chickpea**

Treatments	Days after sowing		
	40	60	80
T1 : Control	0.63	1.52	1.31
T2 : Water soaking	0.71	1.68	1.36
T3 : $CaCl_2$ (2%) seed treatment	0.72	1.96	1.64
T4 : CCC (500 ppm) seed treatment	0.65	1.66	1.33
T5 : CCC (1000 ppm) seed treatment	0.64	1.53	1.33
T6: KCl (1%) foliar spray	0.65	1.75	1.36
T7: KCl (2%) foliar spray	0.65	1.76	1.44
T8 : KNO_3 (1%) foliar spray	0.65	1.78	1.35
T9 : KNO_3 (2%) foliar spray	0.65	1.79	1.46
T10:Ethanol (2%) foliar spray	0.65	1.82	1.46
T11:Ethanol (4%) foliar spray	0.65	1.86	1.52
T12:Methanol (2%) foliar spray	0.65	1.80	1.45
T13: Methanol (4%) foliar spray	0.65	1.84	1.48
Mean	**0.66**	**1.75**	**1.42**
S.Em ±	0.04	0.05	0.04
CD @ 5%	NS	0.14	0.12

4.2.3 Absolute growth rate (g plant^{-1} day^{-1})

The data on absolute growth rate (AGR) indicated significant differences among the treatments at all the stages (Table 9). Among the treatments seed treatment with 2% $CaCl_2$ has recorded significantly higher values followed by seed hardening with cycocel (1000 and 500 ppm), foliar spray of ethanol (4%) and methanol (4%) as compared to control. However, significantly lower values were observed in control at all the stages. But this treatment did not differ significantly with water soaking at 40-60 DAS and water soaking, foliar spray of nutrients, ethanol (2%) and methanol (2 and4%) at 60-80 DAS. Maximum AGR (0.774 g day^{-1}) was recorded in seed hardening with 2% $CaCl_2$ at 60-80 DAS.

4.2.4 Relative growth rate (g g^{-1} day^{-1})

The data on relative growth rate (RGR) indicated significant difference due to treatments at all the stages. It is evident from the Table 10 that RGR increased from 40-60 DAS and declined thereafter. However, at 40-60 DAS, significantly higher RGR values were recorded in application of methanol (2%) followed by foliar spray of ethanol (1%) and nutrients at both levels, seed treatment with cycocel (1000ppm) and $CaCl_2$ (2%). At 60-80 DAS, no significant differences were observed among the treatments.

4.2.5 Net assimilation rate (g dm^{-2} day^{-1})

The observations on net assimilation rate (NAR) indicated significant differences due to treatments at all the stages (Table 10).The net assimilation *rate was maximum at* 40-60 DAS *and decreased thereafter at* 60-80 DAS. At 40-60 DAS, significantly higher net assimilation rate was found in seed

Table 9. Influence of seed hardening techniques, use of growth retardant and chemicals on crop growth rate (g dm^{-2} day^{-1})and absolute growth rate (g $plant^{-1}$ day^{-1})at different growth stages in chickpea

Treatments	CGR		AGR	
	40-60	60-80	40-60	60-80
T1 : Control	7.1	12.8	0.211	0.383
T2 : Water soaking	9.8	14.6	0.294	0.438
T3 : $CaCl_2$ (2%) seed treatment	14.0	25.8	0.425	0.774
T4 : CCC (500 ppm) seed treatment	11.8	23.4	0.354	0.703
T5 : CCC (1000 ppm) seed treatment	13.8	22.3	0.416	0.670
T6: KCl (1%) foliar spray	10.5	12.6	0.315	0.379
T7: KCl (2%) foliar spray	11.7	14.0	0.351	0.420
T8 : KNO_3 (1%) foliar spray	12.3	15.0	0.369	0.450
T9 : KNO_3 (2%) foliar spray	12.7	15.0	0.380	0.451
T10: Ethanol (2%) foliar spray	12.9	14.3	0.386	0.429
T11:Ethanol (4%) foliar spray	13.3	19.4	0.399	0.581
T12: Methanol (2%) foliar spray	12.4	15.3	0.371	0.458
T13: Methanol (4%) foliar spray	12.8	17.2	0.382	0.516
Mean	**11.9**	**17.1**	**0.358**	**0.512**
S.Em ±	0.4	0.7	0.032	0.048
CD @ 5%	1.3	1.9	0.095	0.140

Table 10. Influence of seed hardening techniques, use of growth retardant and chemicals on relative growth rate (g g^{-1} day^{-1}) and net assimilation rate (g dm^{-2} day^{-1})at different growth stages in chickpea

Treatments	RGR		NAR	
	40-60	60-80	40-60	60-80
T1 : Control	0.0261	0.0177	0.260	0.037
T2 : Water soaking	0.0275	0.0157	0.320	0.039
T3 : $CaCl_2$ (2%) seed treatment	0.0301	0.0188	0.680	0.057
T4 : CCC (500 ppm) seed treatment	0.0297	0.0197	0.350	0.026
T5 : CCC (1000 ppm) seed treatment	0.0310	0.0174	0.420	0.027
T6: KCl (1%) foliar spray	0.0337	0.0145	0.450	0.049
T7: KCl (2%) foliar spray	0.0329	0.0142	0.510	0.038
T8 : KNO_3 (1%) foliar spray	0.0348	0.0147	0.540	0.070
T9 : KNO_3 (2%) foliar spray	0.0346	0.0144	0.570	0.038
T10: Ethanol (2%) foliar spray	0.0356	0.0138	0.610	0.044
T11:Ethanol (4%) foliar spray	0.0355	0.0168	0.660	0.052
T12: Methanol (2%) foliar spray	0.0361	0.0150	0.570	0.046
T13: Methanol (4%) foliar spray	0.0353	0.0159	0.620	0.057
Mean	**0.0325**	**0.0160**	**0.505**	**0.045**
S.Em ±	0.0017	0.0007	0.024	0.003
CD @ 5%	0.0049	0.0022	0.069	0.010

hardening with 2% $CaCl_2$ followed by ethanol (4%) and methanol (4%) as compared to control. However control recorded the significantly lower NAR. At 60-80 DAS, application of KNO_3 (1%) recorded significantly higher NAR, which was on par with seed hardening with 2% $CaCl_2$, methanol (4%) and ethanol (4%) as compared to control.

4.2.6 Specific leaf weight (mg cm^{-2})

The data on specific leaf weight (SLW) indicated significant differences due to various treatments at all the stages except at 40 DAS (Table 11). The specific leaf weight increased continuously from 40 to 60 DAS and declined thereafter at 80 DAS. Among the treatments. Seed hardening with cycocel (1000 ppm) recorded significantly higher values followed by seed hardening with cycocel (500 ppm) which is on par with seed hardening with 2% $CaCl_2$, foliar spray of KCl (1%), KNO_3 (1% and 2%), ethanol (2 and 4%) and methanol (4%) at 60 DAS and seed treatment with 2% $CaCl_2$ at 80 DAS. Significantly lower SLW was observed in control, but it did not differ significantly with water soaking and application of nutrients at 80 DAS.

4.2.7 Leaf area duration (days)

The data pertaining to leaf area duration (LAD) presented in Table 12 indicated significant differences due to treatments at all the stages. It increased from 40-60 DAS to 60-80 DAS. Among the treatments, seed hardening with 2% $CaCl_2$ significantly increased leaf area duration followed by foliar spray of ethanol (4%) and methanol (4%) as compared to control at all the stages. However, significantly lower leaf area duration was observed in control at all the stages but it did not differ significantly with water

Table 11. Influence of seed hardening techniques, use of growth retardant and chemicals on specific leaf weight (mg cm^{-2}) at different growth stages in chickpea

Treatments	Days after sowing		
	40	60	80
T1 : Control	5.54	5.67	4.76
T2 : Water soaking	6.29	6.69	5.51
T3 : $CaCl_2$ (2%) seed treatment	7.50	7.96	7.52
T4 : CCC (500 ppm) seed treatment	7.29	8.58	8.32
T5 : CCC (1000 ppm) seed treatment	7.98	9.84	8.72
T6: KCl (1%) foliar spray	4.72	6.57	4.92
T7: KCl (2%) foliar spray	5.68	7.23	5.62
T8 : KNO_3 (1%) foliar spray	5.34	7.86	5.63
T9 : KNO_3 (2%) foliar spray	5.64	7.90	5.22
T10:Ethanol (2%) foliar spray	5.68	8.00	6.34
T11:Ethanol (4%) foliar spray	5.97	8.13	7.11
T12:Methanol (2%) foliar spray	5.12	7.47	6.22
T13: Methanol (4%) foliar spray	5.64	7.69	6.12
Mean	**6.03**	**7.66**	**6.30**
S.Em ±	0.48	0.33	0.29
CD @ 5%	NS	0.97	0.86

Table 12. Influence of seed hardening techniques, use of growth retardant and chemicals on leaf area duration (days) at different growth stages in chickpea

Treatments	Days after sowing	
	40-60	60-80
T1 : Control	21.56	28.60
T2 : Water soaking	23.90	30.40
T3 : $CaCl_2$ (2%) seed treatment	26.82	35.97
T4 : CCC (500 ppm) seed treatment	21.75	29.03
T5 : CCC (1000 ppm) seed treatment	22.67	29.30
T6: KCl (1%) foliar spray	24.06	31.13
T7: KCl (2%) foliar spray	24.16	32.03
T8 : KNO_3 (1%) foliar spray	24.37	31.36
T9 : KNO_3 (2%) foliar spray	24.47	32.56
T10:Ethanol (2%) foliar spray	24.76	32.86
T11:Ethanol (4%) foliar spray	25.17	32.86
T12:Methanol (2%) foliar spray	24.53	32.53
T13: Methanol (4%) foliar spray	24.93	33.20
Mean	**24.08**	**31.60**
S.Em ±	0.69	0.94
CD @ 5%	2.04	2.74

soaking, cycocel (1000 ppm) and KCl (1%) at 60-80 DAS. Maximum LAD (35.97 days) was noticed in seed hardening with 2% $CaCl_2$ at 60-80 DAS.

4.2.8 Biomass duration (g day)

The results on biomass duration (BMD) indicated significant differences among all the treatments (Table 13). The biomass duration in all the treatments increased from 40-60 DAS to 80- harvest. Among the treatments seed hardening with 2% $CaCl_2$ has recorded significantly higher values followed by seed hardening with cycocel (1000 and 500 ppm), ethanol (4%) and methanol (4%) as compared to control at all the stages. However, the control recorded the lower biomass duration at all the stages. Maximum biomass duration (535.2 g day) was recorded in seed treatment with 2% $CaCl_2$ at 80- harvest.

4.2.9 Relative water content (%)

The data on relative water content (RWC) presented in table 14 indicated significant differences due to various treatments at all the stages except at 40 DAS, and it decreased from 60 DAS to 80 DAS. Among treatments, pre-sowing seed hardening with 2% $CaCl_2$ significantly increased the RWC followed by seed treatment with cycocel (1000 and 500 ppm), ethanol (4%) and methanol (4%) as compared to control. Similarly, application of KNO_3 (2%) recorded significantly higher RWC as compared to control, but it was on par with other nutrients. Significantly lower RWC was observed in control. Maximum RWC (58.45%) was noticed in seed hardening with 2% $CaCl_2$ at 80 DAS.

Table 13. **Influence of seed hardening techniques, use of growth retardant and chemicals on biomass duration (g-day) at different growth stages in chickpea**

Treatments	Days after sowing		
	40	60	80
T1 : Control	78.8	197.8	288.0
T2 : Water soaking	104.9	251.3	354.0
T3 : $CaCl_2$ (2%) seed treatment	140.2	379.1	535.2
T4 : CCC (500 ppm) seed treatment	119.2	330.7	477.4
T5 : CCC (1000 ppm) seed treatment	135.9	353.3	490.1
T6: KCl (1%) foliar spray	96.9	235.8	326.7
T7: KCl (2%) foliar spray	109.7	263.9	352.5
T8 : KNO_3 (1%) foliar spray	111.2	275.2	376.2
T9 : KNO_3 (2%) foliar spray	115.1	281.5	390.8
T10:Ethanol (2%) foliar spray	114.5	277.6	398.1
T11:Ethanol (4%) foliar spray	118.3	314.4	440.2
T12:Methanol (2%) foliar spray	108.8	274.7	381.7
T13: Methanol (4%) foliar spray	113.9	293.6	408.8
Mean	**112.9**	**286.8**	**401.5**
S.Em ±	8.86	11.31	12.15
CD @ 5%	25.88	33.02	35.47

Table 14. Influence of seed hardening techniques, use of growth retardant and chemicals on relative water content at different stages in chickpea

Treatments	Days after sowing		
	40	60	80
T1 : Control	80.20	52.35	46.16
T2 : Water soaking	81.30	59.26	51.32
T3 : $CaCl_2$ (2%) seed treatment	84.00	68.11	58.45
T4 : CCC (500 ppm) seed treatment	82.20	62.78	54.85
T5 : CCC (1000 ppm) seed treatment	83.50	64.97	56.90
T6: KCl (1%) foliar spray	79.20	59.13	50.83
T7: KCl (2%) foliar spray	81.00	58.86	51.58
T8 : KNO_3 (1%) foliar spray	79.30	59.93	52.18
T9 : KNO_3 (2%) foliar spray	80.20	60.68	52.33
T10:Ethanol (2%) foliar spray	79.40	62.13	53.25
T11:Ethanol (4%) foliar spray	80.50	62.53	54.60
T12:Methanol (2%) foliar spray	79.10	61.57	53.85
T13: Methanol (4%) foliar spray	80.20	62.23	54.50
Mean	**80.80**	**61.12**	**53.14**
S.Em ±	3.698	2.06	1.69
CD @ 5%	NS	6.03	4.96

4.3 BIOCHEMICAL PARAMETERS

4.3.1 Chlorophyll 'a' content (mg g^{-1} fr. Wt)

Significant differences were observed due to various treatments at all the stages of investigation with respect to chlorophyll 'a' content (Table 15). It was observed that the chlorophyll 'a' content decreased from 60 to 80 DAS. Among the treatments, seed hardening with cycocel (1000 ppm) recorded significantly higher value followed by seed hardening with cycocel (500 ppm) and 2% $CaCl_2$ at 60 DAS. While lower value was observed in control, but it did not differ significantly with foliar spray of KCl, KNO_3 at both the levels at 60 DAS and KCl at both the levels at 80 DAS. Maximum chlorophyll 'a' content (1.04 mg g^{-1} fr wt) was observed in seed hardening with Cycocel (1000 ppm) at 80 DAS.

4.3.2 Chlorophyll 'b' content (mg g^{-1} fr wt)

The data on Chlorophyll 'b' content indicated significant differences due to various treatments at both the stages. (Table 15). The chlorophyll'b' content increased at 60 DAS and decreased thereafter. Among the treatments, seed hardening with cycocel (1000 ppm) recorded significantly higher values, which is on par with seed hardening with 2% $CaCl_2$, ethanol (4%) at 60 DAS and cycocel (500 ppm), 2% $CaCl_2$ and ethanol (4%) at 80 DAS as compared to other treatments. Maximum chlorophyll 'b' content was observed in seed hardening with cycocel (1000 ppm) at 80 DAS.

Table 15. Influence of seed hardening techniques, use of growth retardant and chemicals on chlorophyll 'a' and chlorophyll 'b' content at different stages in chickpea

Treatments	Chlorophyll a		Chlorophyll b	
	60 DAS	80DAS	60 DAS	80DAS
T1 : Control	1.30	0.45	0.25	0.12
T2 : Water soaking	1.50	0.57	0.26	0.12
T3 : $CaCl_2$ (2%) seed treatment	1.70	0.84	0.42	0.17
T4 : CCC (500 ppm) seed treatment	1.75	0.88	0.37	0.18
T5 : CCC (1000 ppm) seed treatment	1.86	1.04	0.48	0.20
T6: KCl (1%) foliar spray	1.02	0.50	0.20	0.12
T7: KCl (2%) foliar spray	1.19	0.52	0.28	0.12
T8 : KNO_3 (1%) foliar spray	1.35	0.72	0.32	0.15
T9 : KNO_3 (2%) foliar spray	1.45	0.76	0.42	0.16
T10: Ethanol (2%) foliar spray	1.52	0.79	0.27	0.16
T11: Ethanol (4%) foliar spray	1.62	0.84	0.42	0.17
T12: Methanol (2%) foliar spray	1.55	0.81	0.39	0.16
T13: Methanol (4%) foliar spray	1.60	0.83	0.40	0.16
Mean	**1.49**	**0.73**	**0.33**	**0.15**
S.Em ±	0.07	0.03	0.01	0.01
CD @ 5%	0.20	0.09	0.04	0.04

4.3.3 Total chlorophyll content (mg g^{-1} fr. Wt)

It was evident from the table 16 that significant differences were observed due to various treatments at all the stages of investigation with respect to total chlorophyll content. The total chlorophyll content decreased from 60 to 80 DAS. Among the treatments, seed hardening with cycocel (1000 and 500 ppm), 2% $CaCl_2$, application of ethanol (4%) and methanol (4%) recorded significantly higher values as compared to control at all the stages. However, significantly lower total chlorophyll content was observed in control at all the stages and it was found on par with foliar spray of KCl at both the levels and KNO_3 (1%). Maximum total chlorophyll content 1.24 mg g^{-1} fr. Wt.) was observed in seed hardening with cycocel (1000 ppm) at 80 DAS.

4.3.4 **Nitrate reductase activity (μ moles NO_2 g^{-1} fr. Wt. Hr^{-1})**

The data on nitrate reductase activity presented in table 17 indicated significant differences due to various treatments and it decreased from 60 to 80 DAS. At 60 DAS, significantly higher nitrate reductase activity was found in seed hardening with (2%) $CaCl_2$ followed by cycocel (1000 and 500 ppm) and ethanol (4%) as compared to control. However, significantly lower NRA was observed in control. Among the nutrients, KNO_3 (2%) recorded higher nitrate reductase activity as compared to control, but it was on par with other nutrients. Similar results were also noticed at 80 DAS.

4.3.5 Proline content (μg g^{-1} fr. Wt.)

The results pertaining to proline content presented in table 17 indicated significant differences due to treatments at all the stages. It increased from

Table 16. Influence of seed hardening techniques, use of growth retardant and chemicals on total chlorophyll content at different stages in chickpea

Treatments	Total chlorophyll	
	60 DAS	80DAS
T1 : Control	1.55	0.58
T2 : Water soaking	1.76	0.69
T3 : $CaCl_2$ (2%) seed treatment	2.12	1.01
T4 : CCC (500 ppm) seed treatment	2.12	1.06
T5 : CCC (1000 ppm) seed treatment	2.34	1.24
T6: KCl (1%) foliar spray	1.22	0.62
T7: KCl (2%) foliar spray	1.47	0.64
T8 : KNO_3 (1%) foliar spray	1.67	0.87
T9 : KNO_3 (2%) foliar spray	1.87	0.92
T10:Ethanol (2%) foliar spray	1.79	0.95
T11:Ethanol (4%) foliar spray	2.04	1.01
T12:Methanol (2%) foliar spray	1.94	0.97
T13: Methanol (4%) foliar spray	2.00	0.99
Mean	**1.83**	**0.89**
S.Em ±	0.06	0.05
CD @ 5%	0.19	0.16

Table 17. **Influence of seed hardening techniques, use of growth retardant and chemicals on nitrate reductase activity (μmoles of NO_2/g fresh weight/hr) and proline content (μg g^{-1} fr.wt) at different stages in chickpea**

Treatments	Nitrate Reductase Activity		Proline Content	
	60 DAS	80 DAS	60 DAS	80 DAS
T1 : Control	319.4	207.1	163.0	215.6
T2 : Water soaking	420.8	223.5	166.6	248.1
T3 : $CaCl_2$ (2%) seed treatment	498.1	256.0	218.1	320.6
T4 : CCC (500 ppm) seed treatment	468.1	232.5	190.2	273.8
T5 : CCC (1000 ppm) seed treatment	483.5	238.5	215.9	311.5
T6: KCl (1%) foliar spray	414.7	221.5	188.3	256.1
T7: KCl (2%) foliar spray	416.1	224.2	198.5	274.6
T8 : KNO_3 (1%) foliar spray	426.8	225.5	196.3	262.6
T9 : KNO_3 (2%) foliar spray	434.2	230.2	199.2	282.3
T10:Ethanol (2%) foliar spray	438.1	231.5	206.5	282.5
T11:Ethanol (4%) foliar spray	446.2	236.2	211.9	302.5
T12:Methanol (2%) foliar spray	439.8	233.3	197.4	278.9
T13: Methanol (4%) foliar spray	442.1	234.9	206.2	285.4
Mean	**434.4**	**230.3**	**196.8**	**276.5**
S.Em ±	14.00	6.84	6.12	8.48
CD @ 5%	40.87	19.98	17.87	24.77

60 to 80 DAS in all the treatments. Among the treatments, seed hardening with 2% $CaCl_2$ recorded significantly higher values followed by cycocel (1000 ppm), ethanol (4%) and methanol (4%) as compared to control at all the stages. Significantly lower proline content was observed in control at all the stages.

4.4 YIELD AND YIELD COMPONENTS

4.4.1 Days to 50 per cent flowering

The data on days to 50 per cent flowering has indicated no significant differences due to treatments (Table 18). However, seed hardening with 2% $CaCl_2$ reduced number of days to 50 per cent flowering as compared to other treatments and maximum days taken to 50 per cent flowering was observed in control.

4.4.2 Number of pods per plant

The data pertaining to number of pods per plant indicated significant differences due to treatments (Table18). Among the treatments, seed hardening with 2% $CaCl_2$ recorded significantly higher number of pods (92.50) per plant followed by 1000 and 500 ppm cycocel (85.60 and 75.20), 4% ethanol (69.40) and 4% methanol (68.13) over control (52.00). Among the nutrients, KNO_3 (2%) recorded significantly higher pods per plant as compared to control, but it was on par with other nutrients. Significantly lower pods per plant were observed on control. But, this treatment did not differ significantly with foliar spray of KCl at both the levels and KNO_3 (1%).

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

Pod yield differed significantly among the treatments (Table 18). All the treatments increased the pod yield over the control. Among the treatments, seed hardening with 2% $CaCl_2$ recorded significantly higher pod yield (21.20) followed by 1000 and 500 ppm cycocel (19.50 and 18.00), 4% ethanol (17.20) and 4% methanol (17.50) over control(10.20). Among the nutrient treatments, KNO_3 (2%) significantly recorded higher pod yield (15.80) over control , but which is on par with other nutrients. Significantly lower pod yield (10.20g) was recorded in Control.

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

The data on seed yield presented in table 18 indicated that significant differences due to treatments and among the treatments, pre-sowing seed hardening with 2% $CaCl_2$ recorded significantly higher seed yield (18.70 g plant^{-1}) followed by seed treatment with 1000 and 500 ppm cycocel (15.90 and 14.60), 4% ethanol (13.50) and 4% methanol (13.00) over control. (7.85 g plant^{-1}). Significantly lower seed yield was noticed in control, however it did not differ significantly with water soaking. Maximum seed yield of 18.70 g plant^{-1} was observed in seed treatment with 2% $CaCl_2$.

4.4.5 Seed yield (q ha^{-1})

The observations on seed yield on hectare basis also indicated significant differences due to various treatments (Table 19). Among the treatments, pre-sowing seed hardening with 2% $CaCl_2$ showed significantly higher values (25.12) followed by seed treatment with 1000 and 500 ppm cycocel (22.60 and 22.03), 4% ethanol (22.32) and 4% methanol (21.56) as compared to control (15.41). Among the nutrients, KNO_3 (2%) recorded significantly higher values over control, but which is on par with other

Table 18. Influence of seed hardening techniques, use of growth retardant and chemicals on yield and yield components in chickpea

Treatments	Days to 50 per cent flowering	No. of pods per plant	Pod yield per plant (g)	Seed yield per plant (g)
T1 : Control	45.87	52.00	10.20	7.85
T2 : Water soaking	43.66	60.70	13.70	10.50
T3 : $CaCl_2$ (2%) seed treatment	41.76	92.50	21.20	18.70
T4 : CCC (500 ppm) seed treatment	42.50	75.20	18.00	14.60
T5 : CCC (1000 ppm) seed treatment	42.96	85.60	19.50	15.90
T6: KCl (1%) foliar spray	43.76	58.60	13.40	11.20
T7: KCl (2%) foliar spray	42.93	58.60	14.00	12.50
T8 : KNO_3 (1%) foliar spray	43.20	58.60	15.00	12.20
T9 : KNO_3 (2%) foliar spray	43.00	61.03	15.80	12.90
T10: Ethanol (2%) foliar spray	43.73	67.50	16.50	13.20
T11:Ethanol (4%) foliar spray	42.40	69.40	17.20	13.50
T12: Methanol (2%) foliar spray	43.50	65.20	16.80	12.80
T13: Methanol (4%) foliar spray	42.36	68.13	17.50	13.00
Mean	**43.20**	**67.05**	**16.07**	**12.98**
S.Em ±	1.361	2.340	0.97	0.96
CD @ 5%	NS	6.829	2.84	2.80

nutrients. Significantly lower seed yield (15.41 q ha^{-1}) was noticed in control. Maximum seed yield (25.12 q ha^{-1}) was recorded in seed treatment with 2% $CaCl_2$.

4.4.6 Hundred seed weight (g)

It is evident from the table 19 that, there was no significant increase in 100 seed weight due to treatments. However, seed hardening with 2% $CaCl_2$ recorded maximum seed weight as compared to control.

4.4.7 Shelling percentage (%)

Shelling percentage (Table 19) differed significantly among the treatments and seed hardening with 2% $CaCl_2$ recorded significantly higher shelling percentage (82.30%) followed by seed hardening with 1000 ppm cycocel (81.60), 4% ethanol (80.34) and 4% methanol(79.00). as compared to control (67.10%). Significantly lower values were observed in control.

4.4.8 Harvest index (%)

The data on harvest index indicated significant differences due to treatments (Table 19). Among the treatments seed hardening with 2% $CaCl_2$ recorded significantly higher values (51.40) followed by 4% ethanol (47.50) and 1000 ppm cycocel (47.40) over control (37.30). While, among the nutrients, KNO_3 (2%) recorded significantly higher harvest index values (46.10) as compared to control, but it was on par with other nutrients. Significantly lower harvest index was observed in control. Maximum harvest index (51.40) was observed in seed hardening with 2% $CaCl_2$.

Table 19. **Influence of seed hardening techniques, use of growth retardant and chemicals on yield and yield components in chickpea**

Treatments	Seed yield (q/ha)	100 seed weight (g)	Shelling percent age	Harvest index (%)
T1 : Control	15.41	21.50	67.10	37.30
T2 : Water soaking	18.84	23.20	74.91	42.70
T3 : $CaCl_2$ (2%) seed treatment	25.12	26.50	82.30	51.40
T4 : CCC (500 ppm) seed treatment	22.03	25.20	78.90	46.60
T5 : CCC (1000 ppm) seed treatment	22.60	25.60	81.60	47.40
T6: KCl (1%) foliar spray	18.68	24.80	74.50	44.80
T7: KCl (2%) foliar spray	19.45	25.20	75.40	45.00
T8 : KNO_3 (1%) foliar spray	20.40	25.40	75.50	45.80
T9 : KNO_3 (2%) foliar spray	21.03	25.60	79.70	46.10
T10:Ethanol (2%) foliar spray	21.43	25.50	77.60	46.70
T11:Ethanol (4%) foliar spray	22.32	25.86	80.34	47.50
T12:Methanol (2%) foliar spray	21.31	24.70	78.71	45.10
T13: Methanol (4%) foliar spray	21.56	25.80	79.00	46.70
Mean	**20.78**	**24.99**	**77.50**	**45.60**
S.Em ±	1.05	2.75	1.788	1.242
CD @ 5%	3.07	NS	5.219	3.624

4.5 ECONOMICS

The data on the economic of using seed hardening techniques, use of growth retardant and chemicals in chickpea presented in Table 20 indicated that among various treatments, the seed hardening with (2%) $CaCl_2$ (5.29) recorded higher benefit : cost ratio followed by 500 ppm cycocel (4.30). However, the benefit : cost ratio lowest in control (2.88).

Table 20. Influence of seed hardening techniques, use of growth retardant and chemicals on economics of chickpea

Treatments	Seed yield ($q\ ha^{-1}$)	Gross returns	Additional cost ($Rs.ha^{-1}$)	Total cost of cultivation	Net returns	B: C ratio
T1 : Control	15.41	24656	-	6350	18306	2.88
T2 : Water soaking	18.84	30144	-	6350	23794	3.74
T3 : $CaCl_2$ (2%) seed treatment	25.12	40192	35	6385	33807	5.29
T4 : CCC (500 ppm) seed treatment	22.03	35248	290	6640	28608	4.30
T5 : CCC (1000 ppm) seed treatment	22.60	36160	580	6930	29230	4.21
T6: KCl (1%) foliar spray	18.68	29888	800	7150	22738	3.18
T7: KCl (2%) foliar spray	19.45	31120	1600	7950	23170	2.91
T8 : KNO_3 (1%) foliar spray	20.40	32640	900	7250	25390	3.50
T9 : KNO_3 (2%) foliar spray	21.03	33648	1800	8150	25498	3.12
T10: Ethanol (2%) foliar spray	21.43	34288	666	7016	27272	3.88
T11:Ethanol (4%) foliar spray	22.32	35712	1332	7682	28030	3.64
T12: Methanol (2%) foliar spray	21.31	34096	666	7016	27080	3.85
T13: Methanol (4%) foliar spray	21.56	34496	1332	7682	26814	3.49

1. Basic cost of cultivation = Rs. 6350/ha
2. Price of chickpea seeds = Rs. 16/kg
3. Cost of chemicals
   a) $CaCl_2$ = Rs. 35.00 / kg
   b) Cycocel = Rs. 290.0/25 g
   c) KCl = Rs. 80/500 g
   d) KNO_3 = Rs. 90 / 500 g
   e) Ethanol = Rs. 30 / lit
   f) Methanol = Rs. 30 / lit

Discussion

V. DISCUSSION

Chickpea is normally grown on stored soil moisture from the monsoon rains and the receeding soil moisture availability. The area under chickpea is predominant during *rabi* season and is characterised not only by the limited availability of soil moisture but also by high air temperature particularly at later stages of the crop growth. These conditions would *invariably* limit the yield productivity.

Depending upon the extent of residual profile moisture and the scarce winter rains, chickpea suffer to varying degree of *mounting* moisture stress and consequently productivity declines. To combat such adverse moisture scarcity conditions, matching agro-techniques need to be evolved for various agro-ecological regions. Pre-sowing seed treatments 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 cereals in rainfed areas. Most of the research work done so for has been on understanding the mechanism underlying productivity, but very little has been done with respect to the possibilities of overcoming stresses 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.

In this direction, investigations were carried out to know the influence of seed hardening techniques, use of growth retardant and chemicals on various morphological, physiological, biophysical and biochemical parameters, yield and yield components in chickpea (var. Annigeri-1). The results obtained from this investigation are discussed in this chapter.

5.1 MORPHO-PHYSIOLOGICAL PARAMETERS

Morphological characters such as plant height and total dry matter production and its distribution in different plant parts were significantly influenced by various treatments. In the present investigation significant differences were noticed in the plant height due to the seed hardening treatments, use of growth retardant and chemicals at 60, 80 DAS and at harvest. It was interesting to note that there was increase in the plant height over control except in seed treatment with cycocel (1000 ppm), where there was a decrease in plant height compared to control. Further, the plant height was significantly higher in pre-sowing seed hardening with 2% $CaCl_2$ followed by ethanol (4%) and methanol (4%). This clearly indicated that the mode of action is quite different for different chemicals studied. Similarly in finger millet, seed hardening with 2% $CaCl_2$ was more effective and increased the plant height and such effect was due to redistribution of nutrient reserves leading to cell enlargement and increase in normal cell division (Karivartharaju and Ramakrishnan, 1985). Increase in plant height was due to application of alcohols by maintaining the turgidity of guard cells, which would further help for better plant growth through stomatal regulation. Another possible reason for increased plant height could be the growth promoting activity of methanol and ethanol. Mer, (1957) also reported the growth promoting activity of ethanol in oat seedlings.

The mechanism of reduction of plant height due to the seed hardening with cycocel appears to be due to reduced cell size and cell wall thickening or reduction in cell division activity (Ginzo, 1977). It has been suggested that the embryonic tissue provided a factor the gibberllin which upon depression of the repressed genes in the endosperm brought about the release of amylase, which further induced the breakdown of starch. Since cycocel is a retardant, the absorption of the chemical by the seed is likely to cause antigibberllin effects. The lesser availability of metabolic energy thus, may be responsible for the dwarfism exhibited by cycocel treated seedlings (Paleg, 1969). Similarly, Dighe *et al.*, (1983) indicated that cycocel (500 ppm) significantly reduced the plant height in wheat.

5.2 DRY MATTER PRODUCTION AND ITS PARTITIONING

Dry matter production is an important parameter that determines yield in crops and that of reproductive parts particularly is an important yield contributing character. Although the dry matter production in general is indicative of the efficiency of the genotypes and the pattern in which it is distributed in different plant parts would give a better understanding of the genotypes potential. It is well documented that seed hardening treatments, use of growth retardant and chemicals will have their influence on the production of dry matter and the way in which it is partitioned between different parts of the plant.

In the present investigation, it is found that there was significant increase in dry matter production of leaf, stem and reproductive parts due to seed hardening treatments, use of growth retardant and chemicals at different concentrations. Among the treatments, seed hardening with 2%

$CaCl_2$ followed by cycocel (500 and 1000 ppm), ethanol (4%), methanol (4%) recorded significantly higher leaf, stem and reproductive parts dry weight. Further, it was observed that the extent of increase in dry matter production was more in the reproductive parts as compared to leaf and stem. Moreover, the dry matter accumulation in the leaf increased upto 60 DAS and declined thereafter at harvest in all the treatments. The decline in the leaf dry weight at later stages could be due to translocation of stored assimilates towards the development of reproductive organs.

The amount of total dry matter produced is an indication of the overall efficiency of utilization of resources and better light interception. The data pertaining to total dry matter indicated that, it increased continuously from 40 DAS to harvest. At later stage of the growth, the dry matter accumulated at a decreasing rate, which could be attributed to reduced source activity leading to lesser dry matter accumulation in leaf and stem.

These results are in concurrence with Arjunan and Srinivasan (1989) whose results also revealed that seed treatment with $CaCl_2$ (1%) significantly increased total dry matter production in groundnut. Gurudev Singh *et al.* (1991) also revealed that seed treatment with cycocel (10^{-4}M) significantly increased the root, stem and total dry weight in wheat as compared to control. Patil *et al.* (1999) observed that the height of groundnut plants, number of branches, leaf area and dry matter production increased with an increase in the concentration of methanol upto 20 per cent. The increase in dry matter content could be due to the possibility of reduced net radiation load on leaves by using ethanol or methanol which in turn may promote dry matter accumulation by reducing the respiration thereby maintaining optimum water balance in the leaves for increased photosynthesis and other metabolic processes (Nanomura and Benson, 1992)

5.3 GROWTH AND 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. Various empirical relationships such as crop growth rate (CGR), absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR), and specific leaf weight (SLW) describe the connection between the end point of a long chain of inter dependent processes in the environment and the plant (Watson, 1952).

Leaf area fairly gives a good idea of the photosynthetic capacity of the plant. In the present study, it was observed that the leaf area index (LAI) increased upto 60 DAS and decreased thereafter due to senescence and ageing of the leaves. In general, the seed hardening treatments, use of growth retardant and chemicals showed profound significant effect over these parameters. However, seed hardening with 2% $CaCl_2$ recorded significantly higher LAI followed by ethanol (4%), methanol (4%) and KNO_3 as compared to other treatments. This is in accordance with Koppar (1997) who reported that foliar spray of methanol upto 20 per cent significantly increased the LAI as compared to control. Maitra *et al.* (1998) also reported that seed hardening with 2 per cent $CaCl_2$ recorded significantly higher LAI as compared to control in finger millet. Govindan and Thirumurugan (2000) revealed that foliar spray of KCl (1%) or KNO_3 (1%) or in combination increased the LAI over control in greengram.

Another parameter that is determined by the LAI of two consecutive growth stage is leaf area duration (LAD), which was an useful concept not only for predicting the efficiency of photosynthetic system but also for dry matter production. (Chetti and Sirohi, 1995). It indicated the maintenance of assimilatory surface area over a period of time, which was 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, it increased upto 80 DAS. The seed hardening with 2 per cent $CaCl_2$ recorded significantly higher values followed by ethanol (4%), methanol (4%) and KNO_3 (2%) as compared to other treatments, which indicated that, it was more responsive interms of leaf characters. These results were in confirmity with Wright *et al.* (1983) who observed higher grain yield due to higher LAI and LAD in sorghum. Koppar (1996) revealed that, application of methanol upto 20 per cent increased the LAI and LAD over control in wheat. Maitra *et al.* (1998) reported that seed hardening with 2 per cent $CaCl_2$ recorded significantly maximum LAI and LAD over control in finger millet.

Relative growth rate (RGR) represents the increase in dry matter per unit of dry matter already present per unit time. It was found in the present study that RGR declined with advancement of the crop growth. The decline in RGR with the advancement in crop growth could be due to decline on the rate of dry matter production. The increase in the RGR due to pre-sowing seed hardening treatments, use of growth retardant and chemicals could be due to the effectiveness of these chemicals in increasing not only dry matter production but also the rate of increment in total dry matter. This also could be attributed to increase in photosynthetic efficiency by increasing leaf thickness and retaining more chlorophyll content and efficient translocation of photosynthates. Similarly, Kamala Thirumalaiswamy and Sakharam Rao (1977) reported that, seed treatment with cycocel significantly increased RGR under moisture stress condition and also the size of the leaves was greatly influenced by cycocel.

According to Watson (1952), Crop Growth Rate is a useful character for estimating production efficiency of crop stand and enables to make comparisons between the aspects of study. The computation of CGR at different growth stages indicated that CGR was maximum at 60-80 DAS. In the present study seed hardening treatments, use of growth retardant and chemicals significantly increased CGR over control. Among the treatments seed hardening with $CaCl_2$ (2%) recorded significantly higher values followed by cycocel (1000 ppm), ethanol (4%), methanol (4%) as compared to control. These results are in accordance with Maitra *et al.* (1998) revealed that seed hardening with 2% $CaCl_2$ significantly increased the CGR over control in finger millet. Koppar (1997) reported that foliar spray of methanol upto 20% recorded significantly higher CGR values compared to control in wheat.

In the present study, seed hardening treatments, use of growth retardant and chemicals significantly increased absolute growth rate (AGR) over control at all the stages. The seed hardening with 2% $CaCl_2$ significantly increased the AGR followed by cycocel (1000 ppm), ethanol (4%) and methanol (4%) as compared to control.

Net assimilation rate (NAR), synonymously called as 'unit leaf rate' expresses the rate of dry weight increase at any instant on a leaf area basis with leaf representing an estimate of the size of the assimilatory surface

(Gregory, 1926). The decline in NAR with advancement in the crop growth could be attributed to a decline in the rate of dry matter production with decline in leaf area. Though the leaf area increased upto 60 DAS, the NAR declined from 60-80 DAS. This is not only due to reduce rate of leaf area increase but also due to total dry matter which is evidenced from RGR. The highest values for NAR were recorded in seed hardening with 2% $CaCl_2$, followed by ethanol (4%) and methanol (4%) as compared to control. Similarly, Black (1957) also reported that higher NAR coupled with high RGR in most of the stages resulted in higher dry matter accumulation in barley. Eshanna and Kulkarni (1990) who revealed that pre-sowing seed treatment with $CaCl_2$ (1:3 proportion) recorded maximum NAR over control in maize. Koppar (1997) reported that foliar spray of ethanol (4%) increased the NAR in wheat.

The specific leaf weight (SLW) is the indicator of leaf thickness. The increase in SLW indicates leaf thickness due to stacking of palisade cells. Since, chickpea is a C_3 plant, the photosynthetic efficiency per unit leaf area is low and their increased thickness could probably enhance the photosynthetic efficiency due to stacking of mesophyll and bundle sheath cells thereby recapturing the CO_2 released in photo-respiratory process and leading to an increased total dry matter. The specific leaf weight increased upto 60 DAS and declined thereafter. The specific leaf weight was more in seed treatment with cycocel (500 and 1000 ppm) followed by $CaCl_2$ (2%), ethanol and methanol both at 4 per cent as compared to control.

The 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 sinks. The biomass duration significantly increased due to the seed hardening with 2% $CaCl_2$ followed by cycocel (500 and 1000 ppm), ethanol (4%) and methanol (4%) as compared to control which could be attributed to increased dry matter production and its maintenance. Similarly, Koti (1997) showed positive association between BMD and seed yield in soybean.

A better understanding of different biophysical characters and their relationship with yield and other physiological process is essential. In this direction influence of seed hardening treatments, growth retardant and chemicals was studied. Relative water content (RWC) is a measure of the amount of water present in the leaf tissue and the treatments having higher RWC under stress conditions would be preferable to maintain water balance. In the present study, the seed hardening with 2% $CaCl_2$ recorded significantly higher RWC values followed by cycocel (1000 ppm), ethanol (4%) and methanol (4%) compared to control. These results are in concurrence with Patil (1987) who revealed that pre-sowing seed hardening with $CaCl_2$ (2%) recorded higher RWC in sorghum. Similar results were reported by Ameregowda *et al.* (1994) in wheat.

5.4 BIOCHEMICAL PARAMETERS

Identification of substances, which play an important role in osmoregulation is another approach of screening for drought and temperature tolerance in crop plants. It is well documented that under stress 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). An attempt has been made in the present investigation to find out the physico-chemical changes due to seed hardening techniques, use of growth retardant and chemicals in chickpea.

Significant increase in chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents was observed due to seed hardening treatments, use of growth retardant and chemicals at all the stages. The chlorophyll content increased upto 60 DAS and decreased thereafter at all the stages. Among the treatments, the maximum chlorophyll a, chlorophyll b and total chlorophyll contents were observed in seed hardening with cycocel (1000 ppm). The delay in leaf senescence, increased SLW, reduction in cell size with denser cytoplasm and inhibition of chlorophyll breakdown could be attributed to higher chlorophyll content in cycocel treated plants. These results are in accordance with Cheema (1975) who reported that seed treatment with cycocel increased the chlorophyll content in barley. Similarly, Dighe *et al.* (1983) also reported in wheat.

It is further noticed that application of nutrients increased the chlorophyll content due to the role of nitrogen in delaying the synthesis of ABA and promoting cytokinin activity causing higher chlorophyll retention in leaves. Similarly, Das and Sarkar (1981) noticed that foliar spray of 0.5% KNO_3 significantly increased the chlorophyll content in leaves of rice and wheat and also the increased chlorophyll content due to alcohols might be due to the fact that methyl group of methanol is a part of chlorophyll molecules and helps in synthesis of more chlorophyll. These results are in accordance with Pawar (1996) and Koppar (1997) revealed that application of 2% ethanol increased total chlorophyll content in sorghum and wheat, respectively.

Nitrate reductase activity (NRA) a key enzyme in nitrogen metabolism is known to be regulated by various environmental factors, apart from its own substrate *i.e.* nitrate. The reduction of nitrate to nitrite, catalysed by nitrate reductase enzyme which 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 Kuramagomedov, 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 polyribosome level, reduction in the availability of NADH through the effect on photosynthesis, respiration and changes in redox potential. The status of NR during water deficit is an important determinant of growth. The present study also indicated that NRA increased significantly due to seed hardening treatments, use of growth retardant and chemicals. Among the treatments seed hardening with 2% $CaCl_2$ recorded significantly higher values followed by cycocel (500 and 1000 ppm), ethanol (4%) and methanol (4%) as compared to control. Similarly, Koppar (1997) revealed that foliar spray and methanol (4%) significantly increased the NRA as compared to control in wheat.

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 accumulation could make useful contribution to the osmotic adjustment. If it is confined to cytoplasm, but the direct evidences for this are lacking. Several other roles have also been suggested by Blum and Ebercon (1976) for proline accumulation in addition to osmotic adjustment. 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 noticed that seed hardening with 2% $CaCl_2$ recorded significantly higher proline content followed cycocel (500 and 1000 ppm), ethanol (4%) and methanol (4%) as compared to control at all the stages. These results are in accordance with Patil (1987) who reported that seed treatment with $CaCl_2$ (2%) significantly increased the proline content in sorghum. Similar results were reported by Amaregowda *et al.* (1994) in wheat.

5.5 YIELD AND YIELD COMPONENTS

Grain yield is the manifestation of morphological, physiological, biochemical, biophysical and growth parameters. The influence of seed hardening treatments and foliar spray of chemicals significantly increased the seed yield. The increased seed yield may be attributed to higher dry matter production and its accumulation in reproductive parts, higher SLW, 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, seed yield per plant, and shelling percentage both on plant and area basis increased due to seed hardening treatments viz., (water soaking, $CaCl_2$ and cycocel), nutrients (KCl and KNO_3) and alcohols (ethanol and methanol). The increase in seed yield could be attributed to betterment in the growth parameters *viz.,* CGR, SLW, LAD, and BMD in addition to significant increase in harvest index.

The present study also revealed that the increase in seed yield was significantly more in seed hardening with 2% $CaCl_2$ followed by cycocel. The increase in seed yield was probably due to beneficial effects of seed hardening treatments *viz.,* maximum water absorbing capacity of seeds, more intense photosynthetic activity and more tissue hydration, thereby enabling the plant to resist soil moisture stress more efficiently (Henckel, 1964). This is in confirmity with the findings of earlier researchers that pre-sowing seed hardening with cycocel (50 mg/l) recorded significantly higher yield per plant in okra (Mehrotra,1970). Seed hardening with $CaCl_2$ (1%) recorded significantly higher number of pods per plant and pod yield in groundnut (Arjunan and Srinivasan, 1989).

In addition, the present study also indicated that the application of nutrients like KCl and KNO_3 at both the levels significantly increased the number of pods per plant, seed yield per plant, shelling percentage, and harvest index which are most important yield determining components in chickpea. Several research workers indicated that the foliar application of KNO_3 significantly increased the grain and straw yield in rice and wheat (Das and Sarkar, 1981). There was significant increase in seed yield in greengram due to application of 1% K_2SO_4 and 1% KCl (Sadasivam *et al.*, 1990).

From the present study, it may be inferred that the application of ethanol and methanol with different concentrations would be more effective in increasing the yield potential in chickpea. Similarly, Namomura and Benson (1992) observed increase in the yield of C_3 plants due to foliar spray of 10-50 per cent methanol, and the increase in yield was attributed to methanol acting as ready carbon source for plant. During stress, plants reduce photosynthetic activity, which ultimately affect yield and yield components. Under such condition, foliar spray of methanol might be effective to increase the productivity. Foliar application of ethanol at 3 per cent significantly increased the grain yield in sorghum by 32 per cent (Rao *et al.*, 2000).

5.6 ECONOMICS

The data on cost:benefit ratio indicated that it was maximum with 2% $CaCl_2$ followed by cycocel (500 ppm). The decline in cost:benefit ratio with an increase in concentration of cycocel and other chemicals is mainly because of increase in the cost of chemicals. The net returns and the cost:benefit ratio ratio was higher in seed hardening with $CaCl_2$ (2%) was mainly because of low cost of chemicals. From the point of economics, it was thus inferred that the use of $CaCl_2$ at 2% could be recommended for increasing both unit productivity and also the net returns.

FUTURE LINE OF WORK

1. Identification of physiological parameters which are less prone to environmental factors governing sink size and its development.

2. A comprehensive study on biochemical parameters related to moisture stress situation is to be takenup.

3. Evaluating varieties which can accumulate more osmolytes, maintaining higher RWC under depleting soil moisture conditions.

4. It is worthwhile to study the anatomical changes brought about by different seed hardening techniques and use of other chemicals under soil moisture stress conditions.

Summary

VI. SUMMARY

A field experiment was undertaken to find out the effect of different seed hardening techniques, use of growth retardant and chemicals on morphological, biochemical, yield and yield attributing characters under rainfed condition in chickpea during *rabi* 2003 at College of Agriculture Farm, University of Agricultural Sciences, Dharwad. The experiment consisted of 13 treatments *viz.,* three seed hardening treatments (water soaking, $CaCl_2$, and cycocel). The foliar spray of two nutrients (KCl and KNO_3) and two alcohols (ethanol and methanol). The foliar spray treatments were imposed at 45 and 65 days after sowing. The experiment was laid out in randomized block design with three replications. The results obtained from the present investigations are summerised in this chapter.

1. The plant height increased significantly due to the seed hardening treatment with 2% $CaCl_2$ and foliar spray of ethanol (4%) and methanol (4%) as compared to control.

2. Dry weight of leaf, stem and reproductive parts increased significantly due to seed hardening with 2% $CaCl_2$, cycocel (500 and 1000 ppm) and foliar spray of ethanol and methanol. The nutrients KCl and KNO_3 also increased the dry matter content. It was also found that leaf dry weight increased upto 60 DAS and decreased thereafter but the dry weight of reproductive parts increased upto harvest.

3. The leaf area index increased upto 60 DAS and declined thereafter. The treatment seed hardening with 2% $CaCl_2$, foliar spray of ethanol *and* methanol increased the leaf area index as compared to control.

4. The pre-sowing seed hardening techniques, use of growth retardant and chemicals significantly increased CGR, AGR from 40 to 80 DAS and RGR and NAR significantly increased upto 40-60 DAS and declined thereafter.

5. Leaf area duration (LAD) increased from 40-60 DAS to 60-80 DAS due to seed hardening techniques, use of growth retardant and chemicals. BMD also followed the similar trend.

6. Specific leaf weight (SLW) increased significantly upto 60 DAS and declined thereafter due to the seed hardening techniques, use of growth retardant and chemicals. However, higher SLW was found with seed hardening with cycocel (500 and 1000 ppm).

7. There was a significant increase in chlorophyll a, chlorophyll b and total chlorophyll contents due to various treatments at all the stages. However, the maximum chlorophyll content was observed in seed hardeing with cycocel (1000 ppm).

8. The relative water content (RWC) was recorded significantly higher in seed hardening with 2% $CaCl_2$ followed by cycocel (1000 and 500 ppm) and foliar spray of ethanol at 60 and 80 DAS.

9. Nitrate reductase activity increased as growth advanced upto 60 DAS. Significant differences were found due to seed hardening techniques, use of growth retardant and chemicals as compared to control. However, seed hardening with 2% $CaCl_2$ recorded significantly higher values as compared to cotnrol.

10. There was a significant increase in proline content due to various treatments at all the stages. However, the maximum proline content was observed in seed hardening with 2% $CaCl_2$ at all the stages.

11. The seed yield and yield components *viz.,* number of pods per plant, pod yield per plant, seed yield per plant and shelling percentage showed significantly higher values due to seed hardening techniques, use of growth retardant and chemicals as compared to control, whereas the number of days to 50 per cent flowering showed non-significant. The maximum harvest index was obtained with seed hardening with 2% $CaCl_2$ followed by cycocel (1000 ppm).

12. Based on the above results, it is concluded that, the seed hardening with 2% $CaCl_2$ and cycocel (500 ppm) is more effective and economical in increasing the yield in chickpea.

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AVENUES TO IMPROVE THE PRODUCTIVITY POTENTIAL UNDER RECEDING SOIL MOISTURE CONDITION IN CHICKPEA (*Cicer arietinum* L.)

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ABSTRACT

A field experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *rabi* 2003 to study the influence of seed hardening techniques, growth retardant and chemicals on various morpho-physiological, biochemical traits, yield and yield components in chickpea var. Annigeri-1. The experiment was laidout in randomized block design with three replications. The treatments consists of seed hardening chemicals *viz.,* water soaking, $CaCl_2$, cycocel, two nutrients *viz.,* KCl, KNO_3 and two alcohols *viz.,* ethanol and methanol.

Significant differences were observed for various morpho-physiological, biochemical and yield and yield attributes due to seed hardening techniques, use of growth retardant and chemicals. Significant increase in plant height, dry matter in leaf, stem and reproductive parts and total dry matter content was due to treatments as compared to control. The growth parameters *viz.*, LAI, AGR, CGR, RGR, NAR, SLW, LAD and BMD increased significantly due to seed hardening with two per cent $CaCl_2$, cycocel (500 and 1000 ppm) and application of four per cent ethanol and methanol. The biochemical parameters *viz.,* total chlorophyll content, nitrate reductase activity and proline content increased significantly due to seed hardening with $CaCl_2$ (2%), cycocel (500 and 1000 ppm) and application of ethanol (4%) and methanol (4%).

Seed hardening with two per cent $CaCl_2$ also recorded significantly higher seed yield followed by cycocel (500 and 1000 ppm), application of ethanol (4%) and methanol (4%) and the increased yield was due to higher number of pods per plant, pod yield per plant, test weight and harvest index. From the point of economics seed hardening with two per cent $CaCl_2$ was more effective and economical in increasing the yield and also the net returns.