CHAPTER VI

Summary

Arising human population and changing pattern of land use mean that world food production rate will need to be increased. The limiting factors, like biotic and abiotic stresses check the sufficient biomass production during favourable growing periods. An important limiting factor, which reduces the legume crop production, is Root Knot Nematode (RKN). To check the formation of Root knots, many nematicides have been used, since ages. These nematicides no doubt very effective to control Root knots, but they are also spoiling the soil microflora as well as giving negative impact on the production.

Due to the serious hurdle in nematode control is the prohibitive cause of nematicidal chemical as well as their toxicity in the soil, many workers carried-out work on different indigenous plant extracts for the management of RKN (Husain and Masood, 1975; Gommers, 1981; Gommers and Barker, 1988; Zuckerman and Esnard, 1994; Faris and Zhang, 1999; Tsay, 1999; Chitwood, 2002). Many members of Compositae (Asteraceae) have excellent allelopathic potential and the extract can be used as herbal nematicides (Stachon and Zindel, 1980; Eze and Gill, 1992; Ratwat et al., 2002; Bogatek et al., 2006; Batish et al., 2007; Ilori et al., 2007, 2010; Javed and Asghari, 2008; Javaid et al., 2009; Chon and Nelson 2010). Among Asteraceae, P. hysterophorus L. (carrot grass), a somewhat unattractive and aggressive weed native to Southern-North America, Central America (Picman and Picman, 1984), with in the last 100 years has occupied almost all the regions of the world. As an exotic weed, accidentally
introduced in India and the earliest record goes back to 1814 by William Roxburgh, ‘the Father of

Indian Botany’ (Paul, 2010). Many efforts are being made to control the growth or to eradicate this weed by different researches (Jayachandra, 1971; Francis, 1978; Rajendrudu and Rama Das, 1981; Jayanth, 1986; Joshi, 1991, 2006; Evans, 1997; Goyal and Brahma, 2001; Tamado and Milberg, 2002, 2004; Gupta, 2008).

This situation demands that efforts should be made to develop an alternative technology for weed control. Allelopathy could be an appropriate potential technology for this purpose. This study was initiated to survey Parthenium plant for its susceptibility to *M. incognita* and to evaluate their effect on this nematode. However, formulating this plant extract is essential for commercial use of the nematicidal extracts. Cowpea production is beset by an array of pests RKN and other diseases that can cause serious devastation, thus leading to reduced yield and low profitability (Blade et al., 1997). Keeping in view, the studies were conducted to use the potentials of Parthenium extracts having nematicidal compound to control RKN in cowpea.

**I. Screening Experiment**

The screening experiment was set to study the effect of different concentrations of Parthenium extracts (PE), i.e., RE (root extract), SE (stem extract), LE (leaf extract) and FE (flower extract) on different germination parameters. These parts of plant were used for the preparation of extracts. The samples of this weed were cut into fine pieces, immersed in lukewarm water (1.4 mg/ml) and kept it for 24 hrs at room temperature. The Stock solution was prepared after sieving
through 2mm mesh. From the stock solution, 20, 40, 80, 120, 140, 160 and 200% concentrations were prepared with distilled water (DW), against control. The results are presented in Tables A to E; Fig A and B and Plates No.1 and 2.

---

**Summary**

**Section A**

**Seed Germination Parameters**

The observations revealed that all the concentrations initiate early germination, except 200% of RE, as compared to control (Table-A). With 80% of RE, the maximum germination was 80% (non-significant difference with control). The higher concentrations (120 to 200%) showed significant reduction in G%. Under SE treatment, the maximum germination was recorded with 20% concentration, till 3rd day. Under LE treatment, only with 20% of concentrations reached G% upto 100%, till 3rd day and FE treatment also, 20% concentration showed 100% germination, till 3rd day, as compared to control (80% G% till 9th day).

The initiation of germination, the growing seedlings required the addition of water from 5th day with different treatments (Table-B). Under RE treatment, there was a significant reduction (50%) in the water addition, with 20 to 60%, while 80 and 100% of RE showed 46.15% of reduction. Other higher concentrations, 120 to 200% of RE also showed remarkable reduction in water addition followed by reduction in G% (Table-A). With higher concentrations of SE, water addition was reduced with reduction in the germination. Overall, with 20% of SE, 53.84% reduction, with 40 and 60% of SE, 50% reduction in water addition was reported, still the G% was higher than control (Table-A and B). 20, 40 and 60% of LE showed 53.84 and 61.53% water reduction, followed with increase germination till 3rd day (Table-A and B). While, 40 and 60% of
FE, showed 53.84% reduction in water absorption, where G% is 90 and 70%, respectively. Higher concentrations from 80 to 200% also showed 50 to 73.07% reduction in water followed with gradual reduction in G%.

Summary

The data recorded on germination rate index (GRI) also showed increase with lower concentrations i.e. 20 to 120% of RE and FE, 20 to 140% of SE, 20 to 100% of LE (Table-C). The GRI followed the increasing pattern i.e. RE> SE> FE> LE. Speed of germination (SpG) showed that it was increased with all the concentrations of RE, except 200%, while 100 to 160% showed non-significant increase (Table-C). The range of increase under RE treatment was 26.13 to 278.40% and the maximum was noticed with 40 and 60% of RE. Under SE treatment, almost all the concentrations, except 140 and 200% showed increased SpG. The maximum SpG was also recorded with 20% of LE (278.40%), over control. Under FE treatment, SpG was raised with 20 to 100% concentrations.

Coefficient of velocity of germination (CVG) showed that it was increased with lower concentration of PE, while higher concentrations i.e. 160 and 200% of RE, LE, and FE, either showed non-significant change or reduction (Table-C). Emergence index (EI) showed that it was increased from 1.50 to 3.75 fold with different concentrations of PE (Fig,-A). The optimum concentrations to increase EI were 40% of RE, LE and FE, 20% of SE (3.75, 2.63, 1.97, 1.97 fold increase, respectively), over control. The range of increase showed the pattern with different extracts as RE> SE> LE> FE.

Relative seed germination (RSG) showed that it was increased with 20 to 140% of RE, 20 to 60% of SE, 20 to 100% of LE, 20 to 80% of FE. The maximum RSG recorded with 20 to 60% of
RE and SE (150). The higher concentrations (160 and 200% of RE, 140 and 200 of SE, 120 to 200% of LE and 100 to 200% of FE) reduced the RSG (Table-D). Relative root elongation (RRE) showed that all the concentrations of LE and lower concentrations of RE were more effective than SE and FE, over control (Table-D). 60% of RE, 20 and 40% of SE showed similar RRE, as that of control, while 60 to 200% showed significant

**Summary**

enhancement in RRE and the best reported with 60% of LE (241.33%), over control. All the concentrations of FE were either non-significant or significantly reduced the RRE. The lower concentrations of all the PE treatments significantly enhanced the seedling growth (SG, cm), while 140 to 200% of RE and LE, 120 to 200% of SE, and 100 to 200% of FE, either significantly reduced or non-significantly changed the SG (Table-D).

**Seedling Growth Parameters**

The data recorded in root length of seedlings (cm) showed invariable increase i.e. from 1.69 to 27.11%, over control (Table-E). The optimum concentrations to increase root length were 120% of RE, LE and FE (20.33%, 18.64%, 20.33%, respectively) and 20% of SE (27.11%), over control. Shoot length of seedlings (cm) was also increased with the concentrations up to 140% of all the extracts (Table-E). 80% of RE treatment, 100% of SE, LE, 20 and 40% of FE showed maximum increase in shoot length. Among all the treatment, 160 and 200% were inhibitory for shoot length.

Fresh weight of seedlings (g) showed significant enhancement with all the concentrations of PE, except 160 and 200% (Table-E). The optimum concentrations among different extracts were, 120% of RE, 20, 120 and 140% of SE, 120% of LE, 80% of FE. Among all the treatments, FE
showed remarkable increase and with 80%, which showed the maximum increase (82.48%), over control. Dry weight of seedlings (g) showed that the remarkable dry matter accumulation in the seedlings was with only few concentrations of PE and the rest of the concentrations, either significantly reduced or non-significantly affect the dry weight (Table-E). The most effective concentration among RE was 40%, and SE treatment showed that all the concentrations were either ineffective or non-significant for dry weight.

**Summary**

increase. Under LE treatment, only 80, 100 and 120% concentrations and FE 60%, which showed significant enhancement in the dry weight.

Parameters provided significant change in Vigour index (VI) with lower concentrations of PE, while higher concentrations (from 80% or above it) were either non-significant or inhibitory for VI (Fig.-B). The optimum concentrations to increase the VI were 40% of RE, 60% of SE, 40% of LE and FE. Increasing pattern of VI under different treatments of PE showed as 40% RE> 60% SE> 40% FE> 40% LE.

**II. Cultural Practices**

The experiment was designed to collect information on growth, productivity and biochemical parameters. Three sets of experiments were conducted during the months from Feb. to June, in the years **2007-2008, 2008-2009** and **2009-2010**. The data produced is an average of nine replicates and three seasons crop. The selected concentrations of Parthenium extracts were 20, 40, 80,120 and 140%, on the basis of preliminary screening experiments. These selected concentrations were prepared by adding glass-distilled water (GDW) with addition of 1%
surfactant, the APSA-80. The treatments were given at three different stages of growth (pre-flowering, flowering and post-flowering), as of foliar spray.

Section B

Growth and Productivity

The observations taken to study the effect of four different parts of PE (RE, SE, LE, FE) on growth and productivity of cowpea, at three stages of plant growth and developments i.e. pre-flowering, flowering and post-flowering (25, 45 and 65 DAS, respectively). The results are presented in Tables- 1 to 20, Figures 1 to 4 and Plate No. 3 to 8.

Summary

A. Morphological Parameters on Growth

Root length (cm) of cowpea under the treatment of different parts of PE showed an increase with all the concentrations, except 140% of RE, SE and FE, at all the three stages, 80 to 140% of RE at 65 DAS, over control (Table-1). The maximum increase recorded with 40% of RE i.e. 22.55%, 25.81% and 14.39%, with 40% of SE, with 20% of LE i.e. 19.71, 20.36 and 15.17% at 25, 45 and 65 DAS, respectively, while 40% of FE showed maximum increase i.e. 33.48% at 45 DAS. The LE showed comparatively less increase, as compared to other extracts. The shoot length (cm) increase was more from preflowering to flowering than flowering to post flowering (Table-2). The cumulative doses, i.e., treatments given at 20, 40, and 60 DAS showed that the enhancement in shoot length recorded at 65 DAS, under different concentrations of PE. The higher concentrations i.e. 140% of RE at 45 DAS, 120% of LE and FE at 45 DAS, 140% of LE and FE at 25 and 45 DAS showed non-significant increase in shoot length.
The maximum increase in the number of laterals, with 80% of RE, 40% of SE, 80% of LE and 40% of FE (32.45%, 29.05%, 37.29% and 45.28%, respectively), over control. The cumulative effect of three treatments is visible with 80% of RE and SE, 40% of LE and FE at 65 DAS. The maximum increase is observed with 40% RE and SE, 20% LE and 80% FE at 25 DAS. At 45 and 65 DAS, about 1.2 to 1.4 fold increase in number of leaves was recorded, with different concentrations. While, higher concentrations i.e. 140% of SE, LE and FE showed non-significant change.

All the concentrations of PE, significantly increased the fresh weight of leaves/plant (g), except 140% of RE, SE, and LE at 25 DAS, 120% SE and FE at 25 DAS, 140% LE and FE at 45 DAS and 80, 120 and 140% of FE at 65 DAS (Table-5). The stimulatory effect of different parts of Parthenium extracts on fresh weight is in the manner of SE> RE> LE> FE. The observations on dry weight of leaves/plant (g) showed 2.41% to 49.37% increase at 25 DAS, 3.28 to 56.64% increase at 45 DAS, while 3.06 to 52.00% increase at 65 DAS, under different treatments (Table-6). Overall, 40% of SE showed the best cumulative effect of three doses given at 20, 40 and 60 DAS, among all the treatments of PE. The comparative effect of all the concentrations of PE on dry weight followed the manner of effect SE> RE> FE> LE.

All the concentrations significantly increased the leaf area, except 140% of RE, LE and FE, at all the three stages of growth, 120% of RE, LE, at 45 and 65 DAS, 120% of SE at 45 DAS (Fig.-1). The optimum concentrations to increase leaf area were, 40% of RE and SE, 20% of LE and 80% of FE at 25, 45, and 65 DAS. The increase in leaf area is more pronounced between 45 to 65
DAS than 25 to 45 DAS. The increasing pattern of leaf area, was SE> FE> RE> LE, as cumulative effect at 65 DAS (Fig.-1).

The observation taken on the fresh weight of plant (g), i.e., stem and root showed significant enhancement. The maximum enhancement in fresh weight was recorded with 40% of SE, (56.46%) at 25 DAS, 20% of FE, (26.21%) at 45 DAS and 140% of RE (22.05%) at 65 DAS (Table-7). Dry weight of plants (g) showed significant enhancement with all the concentrations of RE, except 140% at 25 and 65 DAS, 20% of SE at 25 and 65 DAS, while higher concentrations showed the reduction. LE and FE showed enhancement in fresh weight at 25 DAS only, while at 45 and 65 DAS, all the concentrations were inhibitory (Table-8).

The total biomass of plant (mg) on dry weight basis increased significantly under lower concentrations of RE and SE, at all the three stages of growth (Fig.-2). LE and FE showed enhancement in total biomass, only at 25 DAS with lower concentrations, while all the concentrations of these at 45 and 65 DAS were either inhibitory or non-significant.

**Summary**

enhancement in total biomass, only at 25 DAS with lower concentrations, while all the concentrations of these at 45 and 65 DAS were either inhibitory or non-significant.

**B. Productivity**

The opening of first flower showed that all the PE initiate early flowering, except higher concentrations (Table-9). 40% of RE, 20 and 40% of SE, 40 and 80% LE and 20% of FE showed early flowering. The number of flowers increased with all the concentrations of PE, except 120 and 140% of SE, LE and FE, which either showed non-significant increase or reduction (Table-9). The increase in number of flowers under all the PE treatments showed the pattern RE> SE> FE> LE.
The number of pods/plant till maturity showed that pods are increased significantly with all the concentrations of PE (Table-10). The maximum number of pods noticed with 40% of RE, 80% of SE, 40% of LE and FE, against control. The data on length of pods revealed that it is increased with all the concentrations, except 140% of RE, 120 and 140% of FE and all the concentrations of LE (Table-10). The pattern of increase in length of pods shown by different treatments was SE > RE > FE > LE. The optimum concentrations to increase the number of seeds/pod among the treatment were 40% of RE and SE, 20% LE and FE, over control (Table-11). The increasing pattern followed as SE > RE > LE > FE.

The weight of 100 seeds (g) showed almost similar pattern as that of number of seeds / pod (Table-11). The optimum concentrations among the treatment were 40% of RE, SE, LE, and FE. All the concentrations of PE, significantly increased the seed yield / plant (g), except 120 and 140% of RE, 80, 140% of LE and 140% of FE (Fig-3). The increase in yield followed the pattern as SE > RE > FE > LE. The maximum increase recorded (total yield in q/ha) with 40% of SE, RE and FE, while all the concentrations of LE showed non-significant increase (Fig.-4).

**Summary**

**Section - C**

**I-Nodulation**

The lower concentrations significantly increase the number of nodules, while higher concentrations were either inhibitory or non-significant (Table-12). The maximum increase recorded with 20% of RE, 40% of SE, LE and FE. Other optimum concentrations for maximum
size of nodules (Table-13) were 20% of SE (2.80 mm), 40% of LE (2.89 mm) and 80% of FE (2.59 mm), over control (2.33 mm) at 25 DAS and 40% of RE (3.56 mm), 80% of SE (3.49 mm), 20 and 40% of LE (3.66 mm), over control (2.89 mm) at 45 DAS, while at 65 DAS noticed with 20% of RE (4.83 mm), SE (4.89 mm), LE (4.66 mm) and FE (4.50 mm), as compared to control (4.11 mm).

The colour of nodules showed lots of variations from white to brown grey, at three different stages of growth (Table-14). At initial stage i.e. pre-flowering (25 DAS), almost the nodules were white or light pink, while 20% of RE, 20 to 80% of SE and 40, 80% of LE and FE showed pink colour of nodules. At 45 DAS, the control plant showed pink and reddish brown nodules, while the lower concentrations of the entire PE showed white, pink and dark pink nodules. At post flowering stage (65 DAS), in control plants most of the nodules were brownish grey and few nodules were pink and dark-pink, while under the treatments 20 and 40% of the entire PE showed most of the nodules pink, dark pink, reddish brown and very less nodules brownish grey.

Summary

All the concentrations of PE were promotory for fresh weight (mg) of nodules/plant, except 140% of RE, SE, 120 and 140% of LE, at all the three stages of growth (Table-15). Increasing pattern for fresh weight of nodules with PE was observed as SE> RE> LE> FE (Table-15). The dry weight (mg) of nodules/plant also showed almost similar pattern as that of fresh weight. 20% of RE, SE and FE, and 40% of LE showed less enhancement in dry weight (Table-16).

II-Root Knot Nematode Studies

The effect of aqueous solutions of PE were inhibitory to the number of eggs and active adult nematodes (Table-17; Plate No.-11 a, b and 12 a, b). All the concentrations of PE, except 20% of
RE and SE showed significant reduction in number of active eggs. After 24 hrs of direct treatment, the number of eggs significantly reduced. After 48 hrs of treatment, the numbers of eggs are commonly reduced in control (without Parthenium extract) as well as in treated sets. After 72 hrs of treatment again, the number of eggs increased in control as well as treated sets. (Table-17; Plate No.-12).

On other hand, untreated solution showed three active nematodes / unit area of magnification after 24 hrs of collections, while under the treatments, number of active J$_2$ nematodes were reduced to 1 or nil (Plate No.-11a and 12a). After 48 hrs of treatment, no active J$_2$ nematodes were observed with >40% concentrations (Plate No.-11b and 12b), but after 72 hrs of treatment 1 or 2 active nematodes were observed with 20 to 80% of RE and SE. Under LE and FE treatments, no active nematodes were observed even after 72 hrs (Table-17b). The data collected on number of galls developed on the root surface showed remarkable reduction with different concentrations of PE, when sprayed at three stages of growth (Table-17c; Plate No.-9 and 10). The galls present on untreated plants were 13 at 25 DAS and subsequently increased with the increasing age of plant i.e. 17 at 45 DAS and 24 at 65 DAS. On the other hand, all the treatments of PE reduced the galls by 30.76% to 100%.

**Summary**

On untreated, untreated solution showed three active nematodes / unit area of magnification after 24 hrs of collections, while under the treatments, number of active J$_2$ nematodes were reduced to 1 or nil (Plate No.-11a and 12a). After 48 hrs of treatment, no active J$_2$ nematodes were observed with >40% concentrations (Plate No.-11b and 12b), but after 72 hrs of treatment 1 or 2 active nematodes were observed with 20 to 80% of RE and SE. Under LE and FE treatments, no active nematodes were observed even after 72 hrs (Table-17b). The data collected on number of galls developed on the root surface showed remarkable reduction with different concentrations of PE, when sprayed at three stages of growth (Table-17c; Plate No.-9 and 10). The galls present on untreated plants were 13 at 25 DAS and subsequently increased with the increasing age of plant i.e. 17 at 45 DAS and 24 at 65 DAS. On the other hand, all the treatments of PE reduced the galls by 30.76% to 100%.

**Section D**

**Morphological Stomatal studies**

**Stomatal frequency**
The observation recorded on stomatal frequency at three different stages of plant growth were presented in tables-18 a, b, c. The results indicated that in all the lower concentrations of PE the stomatal frequency increased significantly, while 80% or above, the frequency was reduced non-significantly, on both adaxial and abaxial surfaces. The observations recorded at three subsequent days after each treatment (DAT).

I Treatment (20 DAS)

On the adaxial surface, 40% of RE showed maximum increase, on 22nd and 23rd day (Table-18 a). The optimum increase recorded with 40% of SE i.e. 66.13% at 21st day followed with 66.40% at 22nd day and 66.53% at 23rd day, while with 40% of LE (56.67%) at 21st day, but it was sharply increased on 22nd (57.41%) followed by 23rd day (58.66%), over control. FE treatment also showed less increase in stomatal frequency than SE, RE and LE. As compared to adaxial surface the stomatal frequency was more on abaxial surface (Table-18 a). The maximum increase in frequency was observed with 80% of RE i.e.16.20% on 21, 28.27% on 22 and 32.36% on 23 DAS. With 80% of SE, on three subsequent DAT i.e.17.44% at 21, 29.50% at 22 and 32.78% at 23 DAS, increase was observed. The maximum increase was observed with 40% of LE i.e.11.74% at 21, with 80% i.e. 23.73% at 22 and followed by 28.17% at 23 DAS. On the other hand, 20% of FE showed maximum increase at 21 DAS (5.72%), 80% of FE (14.05%) at 22 and 80% (18.29%) at 23 DAS. The reduction in stomatal frequency followed the pattern FE< LE< RE< SE, on both the surfaces, except lower concentrations (20 to 80%).
II Treatment (40 DAS)

The observations revealed that stomatal frequency was increased at flowering stage under different concentrations of PE, on both the surfaces (Table-18 b). The cumulative effect of two doses shows the pattern of maximum increase as 80% of SE> 80% of RE> 40% of LE> 20% of FE on adaxial and 40% of RE of 80% of SE> 20% of LE> 40% of FE on abaxial surface. The reduction in stomatal frequency followed the pattern FE< LE< RE< SE on adaxial, while FE< LE< SE< RE on abaxial surface.

III Treatment (60 DAS)

At 3rd stage of growth i.e. post-flowering, the stomatal frequency was slightly increased from 2.75% to 7.48% on adaxial and 1.69 to 5.19% on abaxial surface, with different concentrations of PE (Table-18 c). All the concentrations of FE, either showed non-significant or significant reduction in stomatal frequency on three subsequent days of 3rd treatment. The reduction % vary from 4.65 to 8.84%, with different concentrations of FE. The increase in frequency followed the pattern 80% of SE> 80% of RE> 40% of LE on adaxial and 80% of SE> 80% of RE> 40% of LE, on abaxial surface.

Summary

Stomatal Index (SI)

I Treatment (20 DAS)
SI showed little variation on three consecutive days after 1st treatment, i.e., on 21, 22 and 23 DAS, as compared to control. 40% of RE (7.00%), 20% of SE (3.43%), LE (3.43%) and FE (3.43%) on adaxial and 120% of RE (9.69%) 80% of SE (10.37%), 20 to 80% of LE (3.48%, same) and 20% of FE (6.27%) on abaxial surface, were optimum concentrations to increase the SI, over control (Table 19 a).

II Treatment (40 DAS)

SI was increased with almost all the concentrations of PE except 140% of SE and LE, as compared to control (Table-19 b). Overall, on 3rd DAT, the optimum concentrations were 80% of RE (2.02%), 40 % of SE (0.43%), 40% of LE and FE (2.02 and 2.39%, respectively) on adaxial and 20% of RE, SE and LE (1.02, 2.14 and 2.94%, respectively) and 80% of FE (2.89%) on abaxial surface, over control.

III treatment (60 DAS)

Under different treatments, SI was slightly increased (0.42 to 8.07) with lower concentrations of PE (20 to 80%), while higher concentrations were almost inhibitory on both the surfaces (Table-19 c).

Anatomical Studies of Stomata

The anatomical studies on stomata, like variation in guard cell (GCs), subsidiary cells (SCs) and stomatal aperture are presented in Plate No.-13 to 48.

Summary
As generally observed, in cowpea the stomata are paracytic type with two bean shaped GCs and five SCs. The aperture is slit like, but appeared to be eye shaped, when open (Plate No.-13 to 48). Under the effect of PE, several variations were observed like different sizes of GCs, number of SCs, shape and size of stomatal aperture. The unequal size of GCs, which was observed after I treatment (20 DAS) continued to II treatment (40 DAS) then to III treatment (60 DAS). Usually higher concentrations, above 80% showed many variations in the size of GCs. The RE treatment showed unequal GCs, just after I treatment, on 21 DAS both on adaxial and abaxial surfaces with different concentrations (Plate No.-13 A3, A4, A6, B2, B3, B4, B6). This effect was overcome on 22 and 23 DAS and only few concentrations showed the effect i.e. 20 and 140% (Plate No.-15 A2, A6, B2, B6). Similarly II treatment (40 DAS) and III treatment (60 DAS), showed the same effect as in 20 and 140% of RE (Plate No.-18 A2, A6, B2, B6). This effect was continued as cumulative effect, but with 80 to 140% of RE (Plate No.-21 A5, A6, B4, B6).

Almost similar observations on structural variations of stomata were observed with SE, where after I treatment (20 DAS) the higher concentrations showed variations, as unequal GCs (Plate No.-22 to 24, A5, A6, B5, B6). After II treatment of SE (40 DAS), the similar variations with higher concentrations were observed (Plate No.-25 A4, A5, B2, B4, B6; 26 A2, A3, A6, B5, B6; 27 A2, A5, A6, B6). After the III treatment of SE (60 DAS), all the concentrations showed unequal GCs (Plate No.- 28, 29, 30), against control.

LE showed more variations in the size of GCs with higher concentrations on adaxial surface and almost all the concentrations on abaxial surface, just after the I treatment (Plate No.-31 A4, A6, B2, B3, B4, B6). This effect continues upto the 3rd DAT (Plate No.-33 A2-A4, A6, B6). After II treatment, all the concentrations, except 20% on both the surfaces
showed either unequal GCs (Plate No.-34 to 36, A3, A6, B3 to B6) or wavy GCs (Plate No.-34, A4, B3, B5; 35 and 36, A4, B4). After the III treatment, more variations occur in the GCs, i.e. almost all the concentrations either showed unequal, wavy or wing like GCs (Plate No.-37 to 39).

Similarly, FE affects the GCs with higher concentrations just after I (20 DAS), followed by II (40 DAS) and III treatments (60 DAS). The effect of FE was more visible on the adaxial surface than abaxial surface, where unequal GCs were observed after I treatment (Plate No.-40 A3, A4, A6, B2, B6). This effect continued till 3rd day, after I treatment with all the concentrations, except 20% on abaxial surface and almost all the concentrations showed one of the GC invariably larger than control (Plate No. 43-45). The same effect continued after the 3rd treatment and unequal GCs were observed, except in few treatments. The maximum effect of 20% of FE was observed on 63 DAS, as invariably large size of the GC (Plate No. 46-48 A2).

Similarly, it is very much clear from the observations that all the treatments of PE also affect the number and shape of subsidiary cells (SCs) and stomatal aperture. Specifically, under RE treatment, the higher concentrations (120 and 140%) on both the surfaces showed four SCs as well as the shape of SCs was irregular after 1st treatment (20 DAS) and continued till the 3rd treatment (Plate No.-13-21). Three SCs were also observed with 20% of RE on 61 DAS (Plate No.-19 B2) and 80% on 63 DAS (Plate No.-21 A4). Under SE treatment, the lower concentrations (20 and 40%) didn’t vary the number of SCs, but the size was slightly enlarged, while higher concentrations (80 to 140%) showed four SCs on adaxial surface and three or four SCs on abaxial surface. 120% of SE on abaxial surface showed unequal division and six SCs were observed (Plate No.-25 B5) after II treatment.
Summary

Under LE treatment, the numbers of SCs were generally reduced to four, but larger and of variable sizes, after I treatment. This effect was continued after the II and III treatments (Plate No.-31 to39). Similarly, FE treatment also showed variations in SCs on both the surfaces, but with some specific shapes like winged, flattened or wavy (Plate No. 40-42), after I treatment and followed by II and III treatments (Plate No.- 43-48.).

Usually, water treated leaves showed slit like open aperture (eye shaped), while under the PE treatments stomatal aperture appeared to be small, as the size of GC reduced, Although 20% of PE didn’t show much variations, while in higher concentrations, the stomatal aperture was widely opened. Some of the treatments showed very narrow slit like aperture or small rounded pore, under LE treatment (Plate No.- 31 to 33).

Section E

Biochemical Estimations

The data recorded on Chlorophyll contents (mg/g fr.wt. of leaves), i.e. Chl ‘a’, Chl ‘b’, and total Chl are presented in Figure 5, 6, and 7. Chl ‘a’ content was increased, with lower concentrations (20 to 80%) of PE, at all the three stages of growth. The optimum concentration for increasing Chl ‘a’ were, 40% of RE, 80% of SE, 40% of FE. The cumulative effect of three doses were observed as 40% of SE> RE> LE>FE. The increasing pattern was quite variable with different treatments as 80% of RE followed by 20% of LE, 40% of SE and FE. Overall, the treatments showed the promotory effect on Chl. ‘b’ as RE> SE> LE> FE. Total chlorophyll content was
enhanced with all the concentrations of PE, except 140% of SE and LE at 25 DAS. 120 and 140% of RE, SE and LE at 45 DAS, 80 to 140% of FE at 25 and 45 DAS, 120 and 140% of SE, LE and FE at 65 DAS (Fig-7).

Summary

LE at 45 DAS, 80 to 140% of FE at 25 and 45 DAS, 120 and 140% of SE, LE and FE at 65 DAS (Fig-7).

Total protein content (mg/100 mg fr.wt) in nodules revealed that it was increased with all the concentrations of PE, except 140% of RE at 45 DAS, 120% of SE at 45 and 65 DAS, 140% of SE at all the three observations, 120 and 140% of LE at all the three observations, 80% of LE and FE at 65 DAS, 120% of FE at 65 DAS and 140% of FE at all the three observations (Fig.8). Lb content (mg/100mg fr.wt.) in nodules clearly revealed that lower concentrations are more effective, at all the three stage of growth (Fig-9). The optimum concentrations among different treatments were 40% of RE (82.47% increase), 20% of SE (65.79% increase), 40% of LE and FE (144.45 and 70.32%, respectively), over control. Overall, with three cumulative doses at 65 DAS, higher concentrations of RE (80 to 140%), of SE (120 and 140%), of FE (80 to 140%) were inhibitory for Lb content. On the other hand, all the concentrations of LE, except 80% showed significant increase in Lb content.

Protein content (mg/100mg dry wt.) in seeds showed that it was remarkably increased with lower concentrations of all the treatments of PE (Fig-10). The optimum concentrations to increase the protein content were 40% of RE (26.50%), 40% of SE (25.64%), 20% of LE (20.51%) and 20% of FE (21.36%), over control. The higher concentrations showed non- significant increased or reduction in protein content. The pattern of maximum increased with different treatment was 40% RE> 40% SE> 20% FE> 20% LE.
Total soluble sugars (TSS; mg/100mg dry wt.) in seeds was also enhanced with different concentrations of PE, except 140% of RE and LE, 40 to 140% of SE, over control (Fig. 11). The optimum increase was recorded with 40% of RE (23.35%), 20% of SE (12.40%), 20% of LE (15.32%) and 20% of FE (10.94%). The maximum increasing pattern among different treatments of PE showed 40% RE > 20% LE > SE > FE.

Basically, cowpea is a starch protein legume and the results suggest both the parameters i.e. TSS and the total proteins increased in the seeds, in turn we can say the productivity is increased which is very much clear from the observations by the increase in 100 seed weight, seed yield plant (g) and yield in q/ha. Obviously, the improvements in the capture and conversion of light energy have been a central part of crop improvement during the last century. The increase in growth parameters, specifically, the leaf area with chlorophyll content allowing the crop to be extremely efficient at absorbing the solar radiations. The application of allelochemicals in lower concentrations (specifically RE and SE) increased leaf area and also the rate of photosynthesis/unit leaf area.

There are immediate opportunities for management of weed and crop residues and minimize crop losses from allelopathy and also to use allelopathic crops for weed management. Allelopathic-environmental interactions must be considered in efforts to benefit from allelopathy. Allelochemicals may also be adapted to yield stimulants or environmentally sound plant growth regulators. Additionally this enhancement with the nematode pest management and enhanced nodulation can be resulted in the better yield. Thus, incorporating the mechanism of
active variety of allelochemicals and using the dual nature of allelochemicals as growth regulating and nematicidal properties, these can be utilized for promoting the crop yield.

Today with inflation on the rise and inspirations rising, farmers also want a better standard of living. Increasing prices of the agricultural produce can be done only upto a point and

**Summary**

therefore increasing yield and quality of produce are better options to increase farmer’s income and needs to be focused on. The Indian yields are amongst the lowest in the world and have continued to be stagnant or declined over the last decade. Now is the time, we should consider what kind of innovations could be promoted in agriculture and allelopathy is one of the innovative and cost effective method to be incorporated. Therefore, a comprehensive strategy to do something new is required, as the government needs to work towards increasing the yields significantly.