6. SUMMARY

The results of the experiment entitled **"Effect of Phosphorus, Sulphur and Seaweed Sap on Productivity of Chickpea (*Cicer arietinum* L.)"** presented and discussed in the preceding chapters are summarized below:

6.1 EFFECT OF PHOSPHORUS LEVELS

6.1.1 Growth parameters

- The application of graded levels of phosphorus from 20 to 60 kg ha^{-1} significantly increased the plant height of chickpea plant at 30 and 60 DAS and at harvest but recorded at par with 40 kg P_2O_5 ha^{-1}. Pooled data further revealed that application of 60 kg P_2O_5 ha^{-1} increased plant height by 17.67, 9.11 and 8.26 per cent over 20 kg P_2O_5 at 30, 60 DAS and at harvest, respectively.
- Application of 60 kg P_2O_5 ha^{-1} to chickpea crop recorded significant higher branches $plant^{-1}$ at 60 DAS and at harvest over 20 kg P_2O_5 ha^{-1} during both the years and on pooled basis. However, it was at par with 40 P_2O_5 ha^{-1}.
- Across the years dry matter accumulation increased significantly with advancing phosphorus application up to 60 kg P_2O_5 ha^{-1}. On pooled basis 60 kg P_2O_5 ha^{-1} tended to increase dry matter by 7.27, 11.52, 18.00 and 15.36 per cent over 20 kg ha^{-1} at 30, 60, 90 DAS and at harvest, respectively. However, at 30 DAS chickpea crop fertilized with 40 kg P_2O_5 recorded at par with 60 kg P_2O_5 ha^{-1}.
- The dry matter accumulation in different plant parts *viz*., leaf, stem and reproductive parts varied significantly under the influence of phosphorus application at all growth stages. Maximum total DMA at 30 DAS (1.225 g $plant^{-1}$) was recorded under soil enrichment with 60 kg P_2O_5. However, the DMA under 40 kg P_2O_5 was at par with it. DMA in leaf and stem at 30 DAS also differed significantly and accounted similar trends as that of total plant. The contribution of DMA by leaves were (66.12 per cent) more than stem (33.87 per cent) in total DMA at 30 DAS by 60 kg P_2O_5 ha^{-1}.
- The dry matter accumulation at 60 DAS on pooled basis in leaf, stem and reproductive parts were 54.33, 28.76 and 16.91 per cent respectively to that of

total DMA (7.743 g plant^{-1}). At 90 DAS pooled dry matter accumulation in leaf (2.826 g plant^{-1}; 17.26 per cent), stem (5.615 g plant^{-1}; 34.31 per cent) and reproductive parts (7.926 g plant^{-1}; 48.43 per cent) to that of total DMA 16.367 g plant^{-1} was due to application of 60 kg P_2O_5 ha^{-1}, which was significantly superior over 40 kg P_2O_5 ha^{-1} followed by 20 kg P_2O_5 ha^{-1}. Similarly, at harvest 60 kg P_2O_5 ha^{-1} recorded maximum DMA by different plant parts which was significantly superior over 20 and 40 kg P_2O_5 ha^{-1} except reproductive parts where 40 kg recorded at par results with 60 kg.

- Application of 60 kg P_2O_5 ha^{-1} registered significantly higher CGR, AGR, RGR and BMD (between 30-60 and 60-90 DAS) over 20 and 40 kg P_2O_5 ha^{-1}on pooled basis. However, RGR and BMD of chickpea were at par with 40 kg P_2O_5 ha^{-1}.

- Significantly greater chlorophyll content in fresh leaves of chickpea at 60 DAS was observed under the influence of 60 kg P_2O_5 ha^{-1} which was 28.65 and 2.92 per cent higher than 20 and 40 kg P_2O_5 ha^{-1}.

6.1.2 Yield attributes and yield

- Application of 60 kg P_2O_5 ha^{-1} significantly increased the yield attributes *viz.,* pods plant^{-1}, grains pod^{-1}, grains plant^{-1}, grain yield plant^{-1} and 100-grain weight over 20 kg P_2O_5 ha^{-1} and at par with 40 kg P_2O_5 ha^{-1}, except in case of pods plant^{-1} on pooled basis, where 60 P_2O_5 kg ha^{-1} recorded significantly superior over 40 P_2O_5 kg. On pooled basis, increase in phosphorus dose from 20 to 60 kg P_2O_5 ha^{-1} increased pods plant^{-1}, grains pod^{-1}, grains plant^{-1}, grain yield plant^{-1} and 100-grain weight by 13.15, 8.33, 20.98, 25.70 and 6.35 per cent, respectively over 20 kg P_2O_5 ha^{-1}.

- The significantly higher grain, haulm and biological yield were produced by 60 kg P_2O_5 ha^{-1} during both the years and on pooled basis over 20 kg P_2O_5 ha^{-1} but at par with 40 kg. The respective mean increase in grain, haulm and biological yield by 60 kg P_2O_5 ha^{-1} were 14.39, 14.58 and 14.52 per cent and by 40 kg were 10.76, 10.93 and 10.87 per cent, respectively over 20 kg ha^{-1} (1320, 2489 and 3809 kg ha^{-1}). However, harvest index was not affected significantly due to phosphorus levels.

6.1.3 Quality parameters

- The protein content was raised significantly from 21.15 to 22.04 per cent with increase in phosphorus dose from 20 kg to 60 kg ha^{-1}. However, 60 kg P_2O_5 ha^{-1} recorded at par with 40 kg P_2O_5 ha^{-1}. Methionine, cysteine and cystine content was not affected due to phosphorus nutrition.

6.1.4 Nutrient content and uptake

- The chickpea crop under the influence of 60 kg P_2O_5 ha^{-1} accounted for greater N, P, K and S concentration in leaves at 60 DAS and grain and haulm at harvest during both the years and on pooled basis. However, 40 kg P_2O_5 ha^{-1} recorded at par N, K and S content as with 60 kg and P content were increased significantly with graded levels up to 60 kg P_2O_5 ha^{-1} during both the years.

- The maximum N accumulation by chickpea grain and haulm at harvest were found superior when the crop fertilized with 60 kg P_2O_5 ha^{-1}. It was significantly superior over 20 kg P_2O_5 ha^{-1} but failed to give significant improvement over 40 kg P_2O_5 ha^{-1}. The magnitude of increase in total N uptake due to 60 kg P_2O_5 ha^{-1} over 20 and 40 kg P_2O_5 ha^{-1} was 20.01 and 3.38 per cent, respectively.

- Application of 60 kg P_2O_5 ha^{-1} accounted for significantly greater P uptake by grain, haulm and total uptake by chickpea over 20 and 40 kg P_2O_5 ha^{-1} on pooled basis. The magnitude of increase by grain, haulm and total uptake were 21.12, 24.81 and 23.02 per cent over 20 kg P_2O_5 ha^{-1}, respectively.

- The crop fertilized with 60 kg P_2O_5 ha^{-1} significantly increased the K uptake by grain, haulm and total uptake by chickpea over 20 and 40 kg P_2O_5 ha^{-1} on pooled basis. The magnitude of increase was 25.33 and 7.95 per cent in grain, 20.42 and 3.78 per cent in haulm and 21.17 and 4.44 per cent in total K uptake over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

- The crop under the influence of 60 kg P_2O_5 ha^{-1} significantly increased the S uptake over 20 and 40 kg P_2O_5 ha^{-1} on pooled basis. The magnitude of increase was 26.45 and 4.44 per cent in grain, 22.73 and 4.35 per cent in haulm and 24.88 and 4.19 per cent in total S uptake over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

6.1.5 Nutrient status of soil

- Application of 60 kg P_2O_5 ha^{-1} accounted for significantly higher status of available P after harvest of the crop over 20 and 40 kg P_2O_5 ha^{-1}. While available N status of soil significantly influenced upto 40 over 20 kg P_2O_5 ha^{-1}.

6.1.6 Economics

- The economic analysis reveal that compared to 20 kg P_2O_5 ha^{-1} (₹ 26327 ha^{-1}), application of 40 and 60 kg P_2O_5 ha^{-1} tended to increase net returns significantly by ₹ 4223 and 4901 ha^{-1} on pooled basis. However, increase in phosphorus level from 40 to 60 kg failed to account significantly higher net returns. Progressive increase was recorded in B C ratio by advancing phosphorus dose to 40 kg P_2O_5 ha^{-1} by 13.93 per cent over 20 kg P_2O_5 ha^{-1} on pooled basis. However, levels at 40 and 60 kg P_2O_5 ha^{-1} remained at par with economic point of view.

6.2 EFFECT OF SULPHUR LEVELS

6.2.1 Growth parameters

- Sulphur nutrition had significant results on plant height at 30, 60 DAS and at harvest over control. Pooled statistics show that plant height was progressively and significantly increased upto 40 kg S ha^{-1} at 30 DAS and at harvest and remained at par with 20 kg S ha^{-1} at 60 DAS.

- Primary branches $plant^{-1}$ were increased significantly up to 40 kg S ha^{-1} at 60 DAS and at harvest except during 2012-13 and pooled basis at 60 DAS where it remained at par with 20 kg S ha^{-1}. On pooled basis, 40 kg S ha^{-1} tended to increase number of primary branches $plant^{-1}$ by 17.70 and 11.94 per cent over control at 60 DAS and at harvest, respectively.

- Across the year dry matter production increased progressively and significantly with advancing S application up to 40 kg S ha^{-1}, however, it remained at par with 20 kg S ha^{-1} at 30 and 60 DAS. On pooled basis 40 kg S ha^{-1} tended to increase total dry matter by 12.05, 13.80, 17.19 and 16.85 per cent over control at 30, 60, 90 DAS and at harvest, respectively.

- The dry matter accumulation in different plant parts *viz*., leaf, stem and reproductive parts varied significantly under the influence of sulphur

application at all growth stages. Maximum total DMA at 30 DAS (1.246 g plant^{-1}) resulted under application of 40 kg S ha^{-1}. However, the DMA accumulated by 20 kg S ha^{-1} was at par with it. DMA in leaf and stem at 30 DAS also differed significantly and followed similar trends as that of total plant. The contribution of DMA in leaves were (65.89 per cent) more than stem (34.11 per cent) in total DMA at 30 DAS by 40 kg S ha^{-1}.

- The dry matter accumulation at 60 DAS on pooled basis in leaf, stem and reproductive parts were 54.68, 29.09 and 16.49 per cent respectively to that of total DMA (7.718 g plant^{-1}). At 90 DAS pooled dry matter accumulation in leaf (2.923 g plant^{-1}; 18.00 per cent), stem (5.625 g plant^{-1}; 34.65 per cent) and reproductive parts (7.688 g plant^{-1}; 47.35 per cent) to that total 16.236 g plant^{-1} was due to application of 40 kg S ha^{-1}, which was significantly superior over 20 kg S ha^{-1} and control. Similarly, at harvest 40 kg S ha^{-1} recorded maximum DMA by different plant parts which was significantly superior over control and 20 kg S ha^{-1} on pooled basis.
- Significantly higher CGR, AGR, RGR and BMD (30-60 and 60-90 DAS) were recorded under the influence of 40 kg S ha^{-1}over control on pooled basis.
- Significantly greater chlorophyll content of fresh leaves of chickpea at 60 DAS was observed under the influence of 40 kg S ha^{-1} over 20 kg S ha^{-1} and control. On pooled basis 40 kg S ha^{-1} tended to increase chlorophyll content of chickpea leaves by 37.16 per cent more over control.

6.2.2 Yield attributes and yield

- Progressive application of S up to 40 kg S ha^{-1} resulted in significantly greater yield attributes across the years and on pooled basis, however, it was at par with 20 kg S ha^{-1} except grain yield plant^{-1} on pooled basis. Increasing S dose up to 40 kg ha^{-1} increased pods plant^{-1} by 9.44, grains pod^{-1} by 6.77, grains plant^{-1} by 17.53, grain yield plant^{-1} by 18.75 and 100-grain weight by 4.70 per cent over control, respectively on pooled basis.
- Across the years grain yield increased with increasing levels of S up to 40 kg ha^{-1} but the yield levels of 40 kg S ha^{-1} remained at par with 20 kg S ha^{-1}. On pooled basis 40 kg S ha^{-1} maximized grain yields (1546 kg ha^{-1}) which represented 3.83 and 22.99 per cent higher over application of 20 kg S ha^{-1} and

control, respectively. Likewise mean haulm yield was also enhanced significantly by raising S levels up to 40 kg S ha^{-1}. Compared to control (2370 kg ha^{-1}), application of 20 and 40 kg S ha^{-1} tended to increase in haulm yield by 18.69 and 23.21 per cent.

- The biological yield also increased significantly by 23.14 per cent over control (3626 kg ha^{-1}) with the application of 40 kg S ha^{-1}. The harvest index was not affected by S application.

6.2.3 Quality parameters

- The protein content of chickpea grain was raised significantly from 21.06 per cent (control) to 22.16 per cent with 40 kg S ha^{-1}. Similarly, significantly greater methionine, cysteine and cystine content were recorded by 40 kg S ha^{-1} during both the years. On pooled basis, application of 40 kg S ha^{-1} tended to increase protein, methionine, cysteine and cystine content by 5.22, 15.00, 15.38 and 11.22 per cent over control, respectively.

6.2.4 Nutrient content and uptake

- Soil enrichment with 40 kg S ha^{-1} accounted for greater N, P, K and S concentration in leaves at 60 DAS and grain and haulm at harvest of chickpea.

- Application of 40 kg S ha^{-1} accounted for greater N uptake by grain, haulm and total uptake significantly over control and 20 kg S ha^{-1} on pooled basis. The magnitude of increase was 28.11 and 4.68 per cent in grain, 29.74 and 4.03 per cent in haulm and 28.59 and 4.48 per cent in total N uptake over control and 20 kg S ha^{-1}, respectively.

- The crop fertilized with 40 kg S ha^{-1} recorded significantly higher P uptake by grain and total P uptake over control and 20 kg S $ha^{-1}$and remained at par in case of P uptake by haulm on pooled basis. The increase were 29.95 and 6.17 per cent in grain, 28.77 and 3.62 per cent in haulm and 29.30 and 4.77 per cent in total P uptake over control and 20 kg S ha^{-1}, respectively.

- The chickpea under the influence of 40 kg S ha^{-1} recorded maximum K uptake by grain, haulm and total K uptake which was significantly higher over control and 20 kg S ha^{-1} on pooled basis. The magnitude of increase by grain, haulm

and total uptake was 42.20, 40.60 and 40.85 per cent over control, respectively.

- Application of sulphur up to 40 kg ha^{-1} increased the S accumulation by grain, haulm and total uptake significantly over lower levels of sulphur on pooled basis. The magnitude of increase in sulphur accumulation with 40 kg ha^{-1} by grain, haulm and total was 41.15, 37.80 and 39.74 per cent, respectively over control.

6.2.5 Nutrient status of soil

- Sulphur application to chickpea crop had no significant effect on available N, P and K status of soil after harvest of the crop. Significantly greater $SO_4^{-2}S$ status of the soil after crop harvest was observed under the influence of 40 kg S ha^{-1} which accounted 33.48 per cent higher available sulphur status over control on pooled basis.

6.2.6 Economics

- The net returns increased significantly from ₹ 23220 (under control) to ₹ 33324 with 40 kg S ha^{-1}. Similarly greater B C ratio was recorded by 40 kg S ha^{-1} during both years over control but it remained at par with 20 kg S ha^{-1}. On pooled basis soil enrichment with S application at 40 kg ha^{-1} tended to increase net returns and B C ratio by 43.51 and 43.27 per cent over control, respectively.

6.3 EFFECT OF SEAWEED SAP SPRAY

6.3.1 Growth parameters

- Foliar spray of seaweed saps had no significant effect on plant height at 30 DAS but significantly higher plant height was observed with seaweed saps over control at 60 DAS and at harvest. Both the seaweed saps were equally effective in increasing the plant height.

- Primary branches $plant^{-1}$ increased significantly by foliar spray of seaweed saps (*Kappaphycus* and *Gracilaria* saps) at 60 DAS and at harvest over control. On pooled basis *Kappaphycus* and *Gracilaria* saps tended to increase primary branches by 26.43 and 13.38 per cent over control at 60 DAS and by 11.90 and 9.65 per cent at harvest, respectively.

- Total dry matter accumulation plant^{-1} at 60, 90 DAS and at harvest increased significantly by foliar spray of either *Kappaphycus* or *Gracilaria* saps over control during both the years and on pooled basis. On pooled basis application of *Kappaphycus* and *Gracilaria* saps tended to increase dry matter by 15.41 and 10.81; 12.51 and 9.68 and 12.06 and 9.95 per cent at 60, 90 DAS and at harvest, respectively over control. At 30 DAS both the seaweed saps were failed to record significant difference.

- Application of *Kappaphycus* and *Gracilaria* saps to chickpea crop tended to increase dry matter accumulation at 60 DAS on pooled basis in leaf, stem and reproductive parts by 10.47 and 3.11, 25.78 and 24.14 and 16.19 per cent, respectively over control. At 90 DAS pooled dry matter accumulation by these plant parts due to *Kappaphycus* and *Gracilaria* saps increased by 13.52 and 11.10, 9.17 and 8.18 and 14.65 and 10.31 per cent, respectively over control. Similarly, at harvest dry matter accumulation by these plant parts due to *Kappaphycus* and *Gracilaria* saps increased by 13.52 and 11.49, 8.89 and 7.63 and 13.86 and 11.09 per cent, respectively over control.

- Foliar spray of *Kappaphycus* and *Gracilaria* saps, significantly increased the CGR, AGR, RGR and BMD between 30-60 and 60-90 DAS during both the years and on pooled basis over water spray except in RGR at 60-90 DAS during 2013-14 which failed to exhibit significant increase over control.

- Chlorophyll content of fresh leaves at 60 DAS stage increased significantly due to foliar application of *Kappaphycus* sap over control and *Gracilaria* sap. On pooled basis *Kappaphycus* and *Gracilaria* saps tended to increase chlorophyll content by 36.56 and 27.96 per cent more over control.

6.3.2 Yield attributes and yield

- Foliar spray of *Kappaphycus* and *Gracilaria* saps recorded significantly higher yield attributes *viz.*, pods plant^{-1}, grains pod^{-1}, grains plant^{-1}, grain yield plant^{-1} and 100 grain weight over control with their respective mean increase of 9.38 and 7.41; 7.52 and 5.26; 16.08 and 14.10; 17.56 and 16.49 and 7.29 and 3.13 per cent, respectively. However, *Kappaphycus* and *Gracilaria* saps, remained at par with each other except for 100-grain weight where *Kappaphycus* sap recorded significantly higher weight over *Gracilaria* sap on pooled basis.

- Foliar spray of *Kappaphycus* and *Gracilaria* saps significantly increased the grain, haulm and biological yield of chickpea over control during both of the years. The mean increase due to *Kappaphycus* and *Gracilaria* saps in grain yield by 15.96 and 13.43, haulm yield by 16.25 and 13.64 and biological yield by 16.15 and 13.57 per cent was recorded over control, respectively. However, *Kappaphycus* and *Gracilaria* saps remained at par with each other.

6.3.3 Quality parameters

- Protein, methionine, cysteine and cystine content increased significantly by foliar spray of *Kappaphycus* and *Gracilaria* saps over water spray. On pooled basis, application of *Kappaphycus* and *Gracilaria* saps tended to increase protein, methionine, cysteine and cystine by 4.92 and 3.69, 13.00 and 8.00, 9.43 and 6.60 and 9.09 and 6.06 per cent, respectively over control.

6.3.4 Nutrient content and uptake

- Application of *Kappaphycus* and *Gracilaria* saps accounted for greater N, P, K and S concentration in leaves at 60 DAS and grain and haulm at harvest. However, on pooled basis maximum nutritional status in leaves at 60 DAS and in grain and straw were recorded with foliar application of *Kappaphycus* sap but it was at par with *Gracilaria* sap except N content in leaves at 60 DAS.

- Maximum N accumulation in chickpea plant was observed by foliar application of *Kappaphycus* sap which was significantly superior over control and *Gracilaria* sap on pooled basis. The magnitude of increase was 21.69 and 4.09 per cent in grain, 27.84 and 3.50 per cent in haulm and 23.49 and 3.91 per cent in total N uptake over control and *Gracilaria* sap, respectively.

- Application of seaweed saps significantly increased the P uptake in grain, haulm and total over water spray on pooled basis. However, both the seaweed saps were at par to each other. The increase were to the tune of 25.35 and 22.09 per cent in grain, 25.19 and 21.73 per cent in haulm and 25.26 and 21.89 per cent in total P uptake, with application of *Kappaphycus* and *Gracilaria* saps over water spray.

- Maximum K uptake by chickpea grain, haulm and total uptake at harvest was found with foliar application of *Kappaphycus* sap. The magnitude of increase due to foliar application of *Kappaphycus* and *Gracilaria* sap was 30.45 and

26.49 per cent in grain, 28.29 and 23.52 per cent in haulm and 28.64 and 24.00 per cent in total K accumulation over control, respectively. However, both the seaweed saps were at par with respect to K accumulation in different plant parts at harvest in chickpea.

- The maximum S uptake in grain, haulm and total uptake recorded with foliar application of *Kappaphycus* sap which was significantly superior over *Gracilaria* sap and water spray on pooled basis.
- In respect to foliar application of seaweed saps it was seen that *Kappaphycus* and *Gracilaria* saps significantly increased S accumulation in grain, haulm and total uptake over control. But the S accumulation by grain, haulm and total was at par between both the seaweed saps. The magnitude of increase with *Kappaphycus* sap by grain, haulm and total uptake were 26.03, 25.43 and 25.54 per cent, respectively over control.

6.3.5 Nutrient status of soil

- The available nutrient status (N, P, K and S) of the soil after harvest of the chickpea crop was not affected significantly due to application of seaweed saps during both of the years.

6.3.6 Economics

- The economic evaluation indicated that foliar spray of *Kappaphycus* sap realized higher net returns over water spray but it was at par with *Gracilaria* sap. Foliar spray of *Kappaphycus* and *Gracilaria* saps gave additional mean net returns of ₹ 4726 and 3519 ha^{-1} over water spray, respectively.

6.4 INTERACTION EFFECT OF PHOSPHORUS AND SULPHUR

- Progressive application of P up to 60 kg P_2O_5 ha^{-1} and S up to 40 kg ha^{-1} resulted in significantly greater number of pods $plant^{-1}$ and grain yield $plant^{-1}$ by 21.14 and 42.60 per cent over $P_{20}S_0$ on pooled basis, respectively.
- Significantly higher grain, haulm and biological yield on pooled basis was recorded with combined application of 60 kg P_2O_5 ha^{-1} + 40 kg S ha^{-1} over $P_{20}S_0$ by 48.95, 50.00 and 49.68 per cent, respectively.

- Application of 60 kg P_2O_5 ha^{-1} along with 40 kg S ha^{-1} accounted for significantly greater uptake of total N by 70.28, P by 80.22, K by 86.81 and S by 82.65 per cent over the $P_{20}S_0$ on pooled basis, respectively.
- Combined application of 20 kg P_2O_5 ha^{-1} + 40 kg S ha^{-1} recorded highest net returns of ₹ 33929 ha^{-1} and B C ratio of 1.58 on pooled basis.
- The economic analysis reveal that application of 20 kg P_2O_5 ha^{-1} + 40 kg S ha^{-1} tended to increased net returns and B C ratio significantly by 104.72 and 102.56 per cent, respectively over $P_{20}S_0$ on pooled basis.

6.5 CONCLUSION

- The results revealed that application of 40 kg P_2O_5 ha^{-1} resulted in significantly higher grain yield and net returns. Application of 40 kg S ha^{-1} gave significantly higher grain yield and net returns. Amongst seaweed saps, foliar application of *Kappaphycus* sap 10 % resulted in higher chickpea grain yield and net returns. Though it was statistically at par with *Gracilaria* sap 10 % spray.
- Based upon two years experimentations it is concluded that the chickpea crop should be fertilized with 40 kg P_2O_5 and 40 kg S ha^{-1}. The crop should be sprayed with *Kappaphycus* sap 10 % at 30, 45 and 60 DAS.

6.6 FUTURE LINES OF RESEARCH

- To assess integrated use of chemical fertilizers with microbial inoculants to enhance fertilizer use efficiency.
- To test use of seaweed sap at varying concentrations to standardize their use.