4. EXPERIMENTAL RESULTS

The results of field experiment entitled **"Effect of Phosphorus, Sulphur and Seaweed Sap on Productivity of Chickpea (*Cicer arietinum* L.)"**, conducted at the Instructional Farm, College of Technology and Engineering, MPUA&T, Udaipur during two consecutive *rabi* seasons, 2012-13 and 2013-14, are being presented in this chapter. The data pertaining to the effect of different treatments on chickpea crop were statistically analyzed and after evaluating them for test of significance. Result of main effect and interaction which were found significant are presented in this chapter with the help of suitable tables and graphs. Analysis of variances for the data have been presented in the appendices.

4.1 BIOMETRIC STUDIES

4.1.1 Growth parameters

4.1.1.1 Plant height

At 30 DAS

Phosphorus: A perusal of data (Table 4.1) on plant height of chickpea at 30 DAS indicates that height of chickpea plant increased with increasing level of phosphorus. There was significant effect on plant height when phosphorus level increased from 20 to 40 kg P_2O_5 ha^{-1}, and the further increase in up to 60 kg ha^{-1} showed non-significant response. The increase was in order of 13.96 and 15.69 per cent, respectively with application of 40 and 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1} (12.75 cm) during first year while during second year the increase was to the tune of 16.97 and 19.93 per cent, respectively with application of 40 and 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1} (12.14 cm). The pooled analysis confirmed the yearly trend and resulted in increase of 15.34 and 17.67 per cent in plant height, respectively with application of 40 and 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1} (12.45 cm).

Sulphur: The data of plant height (Table 4.1) at 30 DAS reveal significant increase in plant height with increasing levels of sulphur. During first year the increase was to the tune of 14.54 and 19.22 per cent and during second year it was 6.52 and 7.29 per cent, respectively over control due to application of 20 and 40 kg S ha^{-1}. On pooled basis, the magnitude of increase in plant height at 30 DAS with 20 and 40 kg S ha^{-1} was of the order of 10.46 and 13.19 per cent over control, respectively.

Seaweed sap spray: No significant change was observed in the plant height of chickpea at 30 DAS by foliar spray of different seaweed saps i.e. *Kappaphycus* and *Gracilaria* (Table 4.1).

At 60 DAS

Phosphorus: The effect of phosphorus on plant height of chickpea at 60 DAS was significant due to graded levels of phosphorus. Application of phosphorus at 40 kg P_2O_5 ha^{-1} significantly increased the plant height over 20 kg P_2O_5 ha^{-1} but remained at par with further increase to 60 kg P_2O_5 ha^{-1} during both the years of experimentation and on pooled basis (Table 4.1). The increase was to the tune of 8.17 and 0.13 per cent during first year and 7.98 and 1.77 per cent during second year as the phosphorus application rates increased from 20 to 40 and 40 to 60 kg P_2O_5 ha^{-1}, respectively. Pooled analysis showed that plant height increased by 8.08 and 0.95 per cent with increase in phosphorus dose from 20 to 40 and 40 to 60 kg P_2O_5 ha^{-1}, respectively.

Sulphur: The plant height at 60 DAS was significantly increased due to increasing levels of sulphur. An application of 20 kg S ha^{-1} tended to increase the plant height over control but remained at par with 40 kg S ha^{-1} during both the years of study and on pooled basis. Application of 40 kg S ha^{-1} tended to increase of 12.58 and 3.74 per cent over control (34.49 cm) and 20 kg S ha^{-1} (37.43 cm) in plant height on pooled basis (Table 4.1).

Seaweed sap spray: The data (Table 4.1) reveal that foliar application of seaweed saps, either *Kappaphycus* or *Gracilaria* saps, significantly increased the plant height of chickpea over control (water spray) at 60 DAS during both the years and in pooled mean. However both the seaweed saps registered the statistically the similar plant height with each other. Application of seaweed saps at 10% (*Kappaphycus* and *Gracilaria*) registered an increase in plant height of chickpea to the tune of 14.00 and 13.76 per cent, respectively over control (33.79 cm) on pooled basis.

At harvest

Phosphorus: An examination of data (Table 4.1) reveal that plant height of chickpea at harvest increased significantly with the increasing levels of phosphorus application. There was significant response when phosphorus level was increased from 20 kg ha^{-1} to 40 kg ha^{-1} and further increase in P level from 40 to 60 kg ha^{-1} showed non-significant effect on plant height. During first year the increase was of the order of

5.53 and 10.02 per cent while during second year the increase was to the tune of 5.15 and 6.56 per cent, respectively with application of 40 and 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1}. The pooled analysis confirmed the yearly trends as phosphorus application at 40 and 60 kg ha^{-1} resulted in increase of 5.33 and 8.26 per cent in plant height, respectively over application of 20 kg P_2O_5 ha^{-1} (52.89 cm).

Sulphur: An examination of data (Table 4.1) reveal that application of graded levels of sulphur significantly increased the plant height of chickpea at harvest. Significant increase was also recorded up to 20 kg S ha^{-1} but further increase in S levels did not increase the height significantly. During first year the increase was to the tune of 7.07 and 7.81 per cent and during second year 6.78 and 7.54 per cent over control due to application of 20 and 40 kg S ha^{-1}. On pooled basis, application of 20 and 40 kg S ha^{-1} increased the plant height by 6.92 and 7.66 per cent over control, respectively.

Seaweed sap spray: The data (Table 4.1) on plant height of chickpea at harvest reveal that foliar application of seaweed saps (*Kappaphycus* or *Gracilaria*) significantly increased the plant height over control (water spray) during both the years of study and on pooled basis. However, both the seaweed saps were statistically at par with each other. Foliar application of *Kappaphycus* and *Gracilaria* sap at 10 % increased the plant height significantly by 6.42 and 5.09 per cent, respectively over control (53.24 cm) on pooled basis.

4.1.1.2 Number of primary branches per plant

At 60 DAS

Phosphorus: The data presented in Table 4.2 reveal that increasing levels of phosphorus from 20 to 40 kg P_2O_5 ha^{-1} significantly increased the number of primary branches $plant^{-1}$ of chickpea at 60 DAS. However, further increase in phosphorus application to 60 kg P_2O_5 ha^{-1} did not increase it significantly during both the years and on pooled basis. Application of 40 and 60 kg ha^{-1} tended to give 8.04 and 9.52 per cent increase in number of primary branches $plant^{-1}$ at 60 DAS over 20 kg ha^{-1} (3.36) on pooled basis.

Sulphur: An examination of data (Table 4.2) reveal that increasing levels of sulphur significantly increased the number of primary branches $plant^{-1}$ of chickpea at 60 DAS. However, during 2013-14 the number of primary branches $plant^{-1}$ with application of 40 kg S ha^{-1} was at par with 20 kg S ha^{-1}. The increase in branches due to application of 40 kg sulphur ha^{-1} was by 16.35 and 4.43 per cent during 2012-13 and by 19.44 and 2.14 per cent during 2013-14 over control and 20 kg S ha^{-1}, respectively. On pooled basis application of 40 kg S ha^{-1} increased it significantly by 17.70 and 3.27 per cent, respectively over control and 20 kg S ha^{-1}.

Seaweed sap spray: The data (Table 4.2) reveal that foliar application of seaweed saps (*Kappaphycus* or *Gracilaria*) significantly increased the number of primary branches $plant^{-1}$ of chickpea at 60 DAS over control (water spray) during both the years and on pooled basis. The pooled mean indicate that maximum number of primary branches $plant^{-1}$ (3.97) was recorded with application of *Kappaphycus* sap at 10% which was significantly superior over *Gracilaria* sap (10%) and water spray (3.14). Application of *Kappaphycus* sap 10% increased the number of primary branches $plant^{-1}$ significantly by 26.43 and 11.52 per cent, respectively over control i.e. water spray (3.14) and *Gracilaria* sap (10%).

At harvest

Phosphorus: The data reveal significant improvement in number of primary branches $plant^{-1}$ of chickpea at harvest with application of phosphorus. The maximum number of primary branches $plant^{-1}$ during both the years (3.50 and 3.40) was obtained by use of 60 kg P_2O_5 ha^{-1}, though the values were at par with 40 kg P_2O_5 ha^{-1}. When compared on pooled basis, number of primary branches $plant^{-1}$ of 3.14 recorded under 20 kg P_2O_5 ha^{-1}, application of 40 and 60 kg P_2O_5 ha^{-1} increased it significantly by 8.60 and 9.87 per cent, respectively (Table 4.2).

Sulphur: Consistency of yearly and pooled results in respect of effect of sulphur application on number of primary branches $plant^{-1}$ of chickpea is evident from the data. Advancing the rates on S application over 20 kg ha^{-1} recorded non-significant treatment effects during both the years of study and on pooled basis. The data further reveal that application of 20 and 40 kg S ha^{-1} increased the number of primary branches $plant^{-1}$ significantly over control (3.10) by 10.65 and 11.94 per cent, respectively (Table 4.2).

Seaweed sap spray: The data Table 4.2 show that foliar spray of *Kappaphycus* and *Gracilaria* saps significantly increased the number of primary branches $plant^{-1}$ of chickpea at harvest over control (water spray) during both the years of study and on pooled basis. However, both the seaweed saps were statistically at par with each other. Perusal of pooled data further reveal that foliar application of 10% *Kappaphycus* and *Gracilaria* saps significantly increased primary branches per plant by 11.90 and 9.65 per cent, respectively over control.

4.1.1.3 Dry matter accumulation

At 30 DAS

Phosphorus: It is apparent from the data (Table 4.3) that phosphorus levels significantly influenced the dry matter accumulation in different plant parts (leaf, stem and total) of chickpea at 30 DAS. Significant increase in dry matter of chickpea plant (leaf, stem and total dry matter) was registered by increasing P rate from 20 to 40 kg ha^{-1}, though further increase in P rate from 40 to 60 kg ha^{-1} did not increase it significantly during individual year and on pooled data basis. The maximum dry matter accumulation in leaf (0.803 and 0.817 g $plant^{-1}$), stem (0.416 and 0.414 g $plant^{-1}$) and total dry matter (1.219 and 1.232 g $plant^{-1}$) was registered with the application of 60 kg P_2O_5 ha^{-1} during both the years. Pooled means show that application of 40 kg P_2O_5 ha^{-1} resulted in significant hike in dry matter by 7.86, 5.61 and 7.09 per cent in leaf, stem and total dry matter over 20 kg P_2O_5 ha^{-1}, respectively but its effect was at par with that of 60 P_2O_5 ha^{-1} (Table 4.3).

Sulphur: At 30 DAS application of sulphur significantly increased the dry matter accumulation in all plant parts of chickpea (leaf, stem and total dry matter). An application of 20 kg S ha^{-1} tended to increase the dry matter accumulation in leaf, stem and total dry matter of chickpea plant significantly over control but remained at par with 40 kg S ha^{-1} during both the years and on pooled basis. However, over the years and on pooled basis the maximum dry matter accumulation by all the plant parts and total dry matter was recorded with the application of 40 kg S ha^{-1}. On pooled basis, the increase in S levels from control to 20 and 20 to 40 kg ha^{-1} were associated with hike in accumulation of dry matter by 10.03 and 1.11 per cent in leaf, 12.27 and 0.95 per cent in stem and 10.88 and 1.05 per cent in total dry matter plant by chickpea (Table 4.3).

Seaweed sap spray: A uniformity was observed in dry matter accumulation of chickpea (leaf, stem and total dry matter) in the experiment with either water sprays or seaweed saps spray at 30 DAS (Table 4.3).

At 60 DAS

Phosphorus: The dry matter accumulation at 60 DAS was significantly improved by all the plant parts of chickpea (leaf, stem, reproductive parts and total dry matter) with increasing levels of phosphorus. Application of graded levels of phosphorus significantly increased the dry matter accumulation up to 60 kg P_2O_5 ha^{-1} in either years and similar increase was observed in pooled mean (except in dry matter of leaf during both years). The maximum dry matter accumulation during 2012-13 and 2013-14 in leaf (4.174 and 4.240 g $plant^{-1}$), stem (2.220 and 2.234 g $plant^{-1}$), reproductive parts (1.313 and 1.305 g $plant^{-1}$) and total dry matter (7.707 and 7.779 g $plant^{-1}$) was obtained by application of 60 kg P_2O_5 ha^{-1}, respectively. On pooled basis application of 40 kg P_2O_5 ha^{-1} increased dry matter accumulation significantly by 3.51, 11.58, 9.28 and 6.60 per cent and 60 kg P_2O_5 ha^{-1} by 6.37, 19.35, 16.77 and 11.52 per cent, respectively in all plant parts *viz*., leaf, stem, reproductive parts and the total dry matter over 20 kg P_2O_5 ha^{-1} (Table 4.4).

Sulphur: Dry matter accumulation of chickpea plant parts (leaf, stem, reproductive parts and total dry matter) was recorded with significant variations at different levels of sulphur. Dry matter accumulation of chickpea significantly increased with sulphur dose of 40 kg ha^{-1} over control, but it was at par with 20 kg ha^{-1}. During both years of investigation, maximum dry matter (leaf, stem, reproductive parts and total dry matter) was produced under 40 kg S ha^{-1}. On pooled basis, 20 kg S ha^{-1} increased it significantly by 5.20, 27.23, 11.36 and 11.85 per cent and 40 kg S ha^{-1} by 6.98, 29.77, 12.95 and 13.80 per cent, respectively over control by leaf, stem, reproductive parts and total dry matter (Table 4.4).

Seaweed sap spray: Foliar spray of seaweed sap significantly enhanced dry matter accumulation of chickpea (leaf, stem, reproductive parts and total dry matter) over control during 2012-13, 2013-14 and on pooled basis. Maximum dry matter by leaf, stem, reproductive parts and total dry matter was recorded with application of *Kappaphycus* sap during both the years and on pooled basis. When compared with pooled dry matter accumulation of leaf, stem, reproductive parts and total dry matter (3.886, 1.765, 1.118 and 6.769 g $plant^{-1}$) recorded by under control (water spray), foliar application of *Kappaphycus* sap increased it significantly by 10.47, 25.78, 16.19 and 15.41 per cent and *Gracilaria* sap by 4.92, 24.14, 10.64 and 10.89 per cent, respectively (Table 4.4).

At 90 DAS

Phosphorus: The effect of phosphorus application on dry matter accumulation by chickpea plant parts (leaf, stem, reproductive parts and total dry matter) was significantly increased due to graded levels of phosphorus. Mean dry matter of chickpea increased with each increment in phosphorus dose from 20 to 40 and 40 to 60 kg ha^{-1}. Based on pooled results, the increase in dry matter accumulation due to 60 kg P_2O_5 ha^{-1} was by 20.31 and 3.78 per cent in leaf, 13.48 and 3.52 per cent in stem, 20.58 and 9.46 per cent in reproductive parts and 18.00 and 6.36 per cent in total dry matter plant over 20 and 40 kg P_2O_5 ha^{-1}, respectively (Table 4.5).

Sulphur: The increasing levels of sulphur up to 40 kg ha^{-1} brought about significant increase in dry matter production at 90 DAS by all the plant parts (leaf, stem, reproductive parts and total dry matter). Pooled analysis reveal that application of 40 kg S ha^{-1} tended to give an increase in dry matter by 10.89 and 24.97 per cent in leaf, 3.51 and 14.12 per cent in stem, 2.99 and 16.71 per cent in reproductive parts and 4.51 and 17.19 per cent in total dry matter plant of chickpea, respectively over 20 kg S ha^{-1} and control (Table 4.5).

Seaweed sap spray: A cursory look at data (Table 4.5) of both years of investigation and pooled means reveal that foliar application of seaweed saps resulted in significantly higher dry matter accumulation at 90 DAS in chickpea. Application of *Kappaphycus* and *Gracilaria* saps significantly increased the dry matter production of chickpea leaf, stem, reproductive parts and total dry matter crop at 90 DAS during both the years of study and on pooled basis. When compared on pooled basis, dry matter production of leaf, stem, reproductive parts and total dry matter (2.433, 5.038, 6.690 and 14.161 g $plant^{-1}$) recorded under water spray, foliar application of *Kappaphycus* sap significant increased by 13.52, 9.17, 14.65 and 12.51 per cent and with *Gracilaria* sap by 11.10, 8.18, 10.31 and 9.68 per cent, respectively.

At harvest

Phosphorus: The dry matter accumulation of chickpea plant parts (leaf, stem, reproductive parts and total dry matter) was significantly increased due to graded levels of phosphorus. Mean dry matter of chickpea increased with each increment in phosphorus dose from 20 to 40 and 40 to 60 kg ha^{-1}. Based on pooled results, the increase in dry matter accumulation due to 60 kg P_2O_5 ha^{-1} was 19.83 and 3.60 per cent in leaf, 12.42 and 2.77 per cent in stem, 15.92 and 1.30 per cent in reproductive parts and 15.36 and 2.20 per cent in total dry matter plant over 20 and 40 kg P_2O_5 ha^{-1}, respectively (Table 4.6).

Sulphur: The data show that the successive increase in levels of sulphur significantly increased the dry matter of chickpea by all the plant parts (leaf, stem, reproductive parts and total dry matter) during both the years and on pooled basis. On pooled basis increasing levels of sulphur up to 40 kg significantly increased the dry matter of chickpea by all the plant parts (leaf, stem, reproductive parts and total dry matter). Pooled analysis reveal that application of 40 kg S ha^{-1} tended to give an increase in dry matter by 11.21 and 25.94 per cent in leaf, 2.91 and 13.18 per cent in stem, 2.55 and 16.27 per cent in reproductive parts and 4.18 and 16.85 per cent in total dry matter plant of chickpea, respectively over 20 kg S ha^{-1} and control (Table 4.6).

Seaweed sap spray: The data (Table 4.6) of both years of investigation and pooled means reveal that foliar application of seaweed saps resulted in significantly higher dry matter accumulation at harvest in chickpea. Application of *Kappaphycus* and *Gracilaria* saps significantly increased the dry matter production of chickpea leaf, stem, reproductive parts and total dry matter crop at harvest during both the years of study and on pooled basis. When compared on pooled basis, dry matter production of leaf, stem, reproductive parts and total dry matter recorded under control (water spray), foliar application of *Kappaphycus* sap significantly increased by 13.52, 8.89, 13.86 and 12.06 per cent and *Gracilaria* sap by 11.49, 7.63, 11.09 and 9.95 per cent, respectively.

4.1.1.4 Crop growth rate

At 30-60 DAS

Phosphorus: Each incremental dose of phosphorus significantly increased the crop growth rate of chickpea at 30-60 DAS. Application of 60 kg P_2O_5 ha^{-1} recorded maximum crop growth rate during 2012-13, 2013-14 and on pooled basis it was 12.37 and 5.51 per cent higher over 20 and 40 kg P_2O_5 ha^{-1}, respectively (Table 4.7).

Sulphur: Application of increasing levels of sulphur increased the crop growth rate of chickpea at 30-60 DAS. The maximum and significantly superior crop growth rate was recorded with 40 kg S ha^{-1} and it was at par with 20 kg S ha^{-1}. The pooled analysis reveal that compared to control (5.727 g m^{-2} day^{-1}) application of 20 and 40 kg S ha^{-1} increased the crop growth rate by 12.05 and 14.16 per cent, respectively (Table 4.7).

Seaweed sap spray: Foliar application of seaweed saps significantly improved the crop growth rate between 30-60 DAS than water spray during 2012-13, 2013-14 and on pooled basis (Table 4.7). *Kappaphycus* sap recorded maximum mean crop growth rate which was significantly superior over control and *Gracilaria* sap. On pooled basis maximum crop growth rate (6.686 g m^{-2} day^{-1}) was observed by foliar spray of *Kappaphycus* sap, results of which were significantly superior over *Gracilaria* sap and control by 19.01 and 4.81 per cent, respectively. Data further reveal that crop growth rate obtained by *Gracilaria* sap was also significantly superior over control.

At 60-90 DAS

Phosphorus: Each incremental dose of phosphorus up to 60 kg P_2O_5 ha^{-1} significantly increased the crop growth rate of chickpea at 60-90 DAS over lower levels. Application of 60 kg P_2O_5 ha^{-1} recorded maximum crop growth rate during 2012-13, 2013-14 and on pooled basis crop growth rate was 24.45 and 7.96 per cent higher over 20 and 40 kg P_2O_5 ha^{-1}, respectively (Table 4.7).

Sulphur: Application of increasing levels of sulphur up to the maximum level tested i.e. 40 kg S ha^{-1} significantly increased the crop growth rate of chickpea at 60-90 DAS. The pooled analysis reveal that compared to control (7.143 g m^{-2} day^{-1}) application of 20 and 40 kg S ha^{-1} increased the crop growth rate by 12.40 and 20.45 per cent, respectively (Table 4.7).

Seaweed Sap: Foliar application of both the seaweed saps significantly improved the crop growth rate of chickpea at 60-90 DAS than water spray during 2012-13, 2013-14 and on pooled basis (Table 4.7). *Kappaphycus* sap recorded maximum mean crop growth rate. However, its result were statistically at par with *Gracilaria* sap. Mean enhancement in crop growth rate due to *Kappaphycus* and *Gracilaria* saps than water spray was 9.87 and 8.60 per cent, respectively.

4.1.1.5 Absolute growth rate

At 30-60 DAS

Phosphorus: Each increase in dose of phosphorus up to 60 kg P_2O_5 ha^{-1} significantly increased the absolute growth rate of the chickpea crop at 30-60 DAS during both the years and on pooled basis (Table 4.7). Application of 60 kg P_2O_5 ha^{-1} recorded maximum absolute growth rate which was 12.44 and 5.34 per cent higher than 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: Different sulphur levels significantly enhanced the absolute growth rate between 30-60 DAS during both the years and on pooled basis (Table 4.7). Application of 40 kg S ha^{-1} recorded significantly higher absolute growth rate than control and 20 kg S ha^{-1} to the tune of 14.29 and 1.89 per cent, respectively.

Seaweed sap spray: Foliar application of different seaweed saps significantly improved the absolute growth rate at 30-60 DAS over water spray during both the years and on pooled basis (Table 4.7). *Kappaphycus* sap recorded maximum mean absolute growth rate (0.219 and 0.223 g $plant^{-1}$ day^{-1}) which was significantly superior over control and *Gracilaria* sap. Mean enhancement in absolute growth rate due to *Kappaphycus* and *Gracilaria* saps over water spray was 19.46 and 14.05 per cent, respectively. However, effect of *Kappaphycus* sap was significantly superior over *Gracilaria* sap.

At 60-90 DAS

Phosphorus: Application of phosphorus up to 60 kg P_2O_5 ha^{-1} significantly increased the absolute growth rate of chickpea at 60-90 DAS during both the years and on pooled basis (Table 4.7). Application of 60 kg P_2O_5 ha^{-1} recorded maximum absolute growth rate which was 24.24 and 7.89 per cent higher than 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: Different sulphur levels significantly enhanced the absolute growth rate of chickpea between 60-90 DAS during both the years and on pooled basis (Table 4.7). During both the years and on pooled basis application of 20 kg S ha^{-1} recorded significantly higher absolute growth rate over control, whereas, further increase in S dose to 40 kg S ha^{-1} also increased the absolute growth rate over 20 kg ha^{-1}. The pooled data reveal that application of 20 and 40 kg S ha^{-1} statistically increased the absolute growth rate to the tune of 12.29 and 20.34 per cent, respectively over control (0.236 g $plant^{-1}$ day^{-1}).

Seaweed sap spray: Foliar application of different seaweed saps significantly improved the absolute growth rate of chickpea at 60-90 DAS over water spray during both the years of study and on pooled basis (Table 4.7). *Kappaphycus* sap recorded maximum mean absolute growth rate which was statistically at par with *Gracilaria* sap. Mean enhancement in absolute growth rate of chickpea due to *Kappaphycus* and *Gracilaria* saps over water spray was 10.16 and 8.94 per cent, respectively.

4.1.1.6 Relative growth rate

At 30-60 DAS

Phosphorus: With increase in dose of phosphorus from 20 to 40 kg ha^{-1} the relative growth rate was significantly increased at 30-60 DAS during 2012-13 and on pooled basis but response was non-significant due to phosphorus application during 2013-14 (Table 4.8). Application of 60 kg P_2O_5 ha^{-1} recorded maximum relative growth rate which was 1.92 per cent higher over 20 kg P_2O_5 ha^{-1}.

Sulphur: Increase in sulphur levels significantly enhanced the relative growth rate of chickpea between 30-60 DAS over control during 2012-13 and on pooled basis (Table 4.8). However, variations in relative growth rate during 2013-14 was non-significant due to sulphur application. On pooled basis, application of 40 kg S ha^{-1} recorded maximum relative growth rate which was 1.92 and 0.38 per cent higher over control and 20 kg S ha^{-1}, respectively.

Seaweed sap spray: Foliar application of seaweed sap significantly improved the relative growth rate of chickpea at 30-60 DAS over water spray during both the years of study and on pooled basis (Table 4.8). Mean enhancement in relative growth rate due to *Kappaphycus* and *Gracilaria* saps over water spray was 8.03 and 8.84 per cent, respectively.

At 60-90 DAS

Phosphorus: With increase in dose of phosphorus from 20 to 40 and 40 to 60 kg ha^{-1} the relative growth rate of chickpea significantly increased at 60-90 DAS during both the years and on pooled basis (Table 4.8). Application of 60 kg P_2O_5 ha^{-1} recorded maximum and significantly higher relative growth rate which was 13.27 and 3.74 per cent higher over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: Application of sulphur significantly enhanced the relative growth rate of chickpea at 60-90 DAS over control during both the years and on pooled basis (Table 4.8). However, variations in relative growth rate between 20 and 40 kg S ha^{-1} was statistically at par during both the years and on pooled basis. Application of 40 kg S ha^{-1} recorded maximum relative growth rate which was 5.88 and 0.93 per cent higher over control and 20 kg S ha^{-1}, respectively.

Seaweed sap spray: Foliar application of seaweed saps significantly improved the relative growth rate of chickpea at 60-90 DAS over water spray during 2012-13 and on pooled basis, but non-significant response was recorded due to foliar spray of seaweed saps during 2013-14 (Table 4.8). Mean enhancement in relative growth rate due to *Kappaphycus* and *Gracilaria* saps over water spray was 2.88 and 1.92 per cent, respectively.

4.1.1.7 Biomass duration

At 30-60 DAS

Phosphorus: With increase in dose of phosphorus from 20 to 40 and 40 to 60 kg ha^{-1} the BMD of chickpea significantly increased at 30-60 DAS during 2012-13, 2013-14 and on pooled basis (Table 4.8). Application of 60 kg P_2O_5 ha^{-1} recorded maximum BMD which was 11.57 and 4.65 per cent higher over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: Increase in sulphur levels significantly enhanced the BMD of chickpea between 30-60 DAS over control during both the years and on pooled basis (Table 4.8). However, variations in relative growth rate between 20 and 40 kg S ha^{-1} was statistically at par during both the years and pooled basis. Application of 20 and 40 kg S ha^{-1} recorded 13.56 and 11.86 per cent higher BMD over control, respectively.

Seaweed Sap: Foliar application of seaweed sap significantly improved the BMD of chickpea at 30-60 DAS over control during both the years of study and on pooled basis (Table 4.8). Mean enhancement in BMD due to *Kappaphycus* and *Gracilaria* saps over control was 12.50 and 8.33 per cent, respectively.

At 60-90 DAS

Phosphorus: With each increase in dose of phosphorus up to 60 kg ha^{-1} significantly increased the BMD of chickpea at 60-90 DAS during both the years and on pooled basis (Table 4.8). Application of 60 kg P_2O_5 ha^{-1} recorded 16.03 and 5.85 per cent higher BMD over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: Increase in sulphur levels up to 40 kg S ha^{-1} significantly enhanced the BMD of chickpea at 60-90 DAS during 2013-14 and on pooled basis but remained at par with 20 kg during 2012-13 (Table 4.8). Application of 40 kg S ha^{-1} recorded significantly higher BMD over control and 20 kg S ha^{-1} to the tune of 15.81 and 3.46 per cent, respectively.

Seaweed sap spray: Foliar application of seaweed sap significantly improved the BMD of chickpea at 60-90 DAS over control during both the years of study and on pooled basis (Table 4.8). Mean enhancement in BMD of chickpea due to *Kappaphycus* and *Gracilaria* saps over control were 13.38 and 10.19 per cent, respectively.

4.1.2 YIELD ATTRIBUTES

4.1.2.1 Pods per plant

Phosphorus: It is evident from the data (Table 4.9) that increasing levels of phosphorus application up to 60 kg P_2O_5 ha^{-1} resulted in significantly higher number of pods $plant^{-1}$ during both the years and on pooled basis. The data further show that application of 40 kg P_2O_5 ha^{-1} resulted in significant increase in number of pods $plant^{-1}$ over 20 kg P_2O_5 ha^{-1}, but with further increase in dose from 40 kg to 60 kg ha^{-1} the response was non-significant during both the years. On pooled basis, application of 40 and 60 kg P_2O_5 ha^{-1} significantly increased the pods $plant^{-1}$ by 8.37 and 13.15 per cent over 20 kg P_2O_5 ha^{-1}.

Sulphur: A perusal of data reveal that application of 40 kg S ha^{-1} significantly increased the number of pods $plant^{-1}$ of chickpea but remained at par with 20 kg S ha^{-1} in both the years of experimentations as well as on pooled basis. On pooled basis, application of 20 and 40 kg S ha^{-1} tended to increase pods $plant^{-1}$ by 5.97 and 9.44 per cent over control, respectively (Table 4.9).

Seaweed sap spray: The data (Table 4.9) show that foliar spray of seaweed saps (*Kappaphycus* or *Gracilaria*) significantly increased the pods $plant^{-1}$ of chickpea. The maximum number of pods $plant^{-1}$ (43.87 and 42.93 pods $plant^{-1}$) was recorded with foliar spray of *Kappaphycus* sap during the year 2012-13 and 2013-14, respectively. However, the results of both the seaweed saps were statistically at par with each other. When observed on pooled basis, 9.38 and 7.41 per cent increase in pods $plant^{-1}$ were observed through the foliar spray of *Kappaphycus* or *Gracilaria* saps compared to water spray.

Interaction effect of phosphorus and sulphur: The interaction effect of phosphorus and sulphur was found to be significant on pods $plant^{-1}$ during 2012-13 and on pooled basis. However, it was non-significant during 2013-14.During 2012-13 at P_{20} there was no significant effect with various doses of S application on pods plant^{-1}. However, at P_{40}, pods plant^{-1} higher at S_{40} as compare to S_{20} but at par with control. Whereas, at P_{80}, pods plant^{-1} higher at S_{20} over control but at par with at S_{40}. At S_0 the crop not responded to P application, but increase in dose of S to 20 kgha-1 crop observed significant effect with P_{40} and P60 over P_{20}. Maximum pods plant^{-1} in chickpea observed with $P_{40}S_{40}$ and it was at par with$S_{20}P_{60}$. On pooled basis, at P_{20} there was no significant effect of various doses of S on pods plant^{-1}. However at P_{40}, the pods plant^{-1} was statistically higher at S_{40} as compared to control and S_{20}. At P_{60}, the pods plant^{-1} was statistically higher at S_{40} as compared to control and at par with S_{20}. Highest pods plant^{-1} was recorded at $P_{60}S_{40}$ that was statistically at par with $P_{60}S_{20}$ $P_{40}S_{40}$ and significantly superior over control (Table 4.10).

Table 4.10. Interaction effect of phosphorus and sulphur on pods plant^{-1}

Treatment	Pods plant^{-1}								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	38.17	40.87	38.93	37.62	38.91	40.07	37.89	39.89	39.50
P_{40}	40.53	40.28	46.42	40.79	41.70	44.48	40.66	40.99	45.45
P_{60}	40.76	45.68	45.80	41.25	45.92	46.00	41.00	45.80	45.90
S.Em.±	1.13			1.25			0.84		
CD (P=0.05)	3.40			NS			2.43		

4.1.2.2 Grains pod^{-1}

Phosphorus: Phosphorus application over a range of 20 to 40 kg ha^{-1} gave significantly higher grains pod^{-1} during both the years of experimentation and on pooled basis. The maximum grains pod^{-1} (1.43 and 1.42 grains pod^{-1}) were recorded by use of 60 kg P_2O_5 ha^{-1} but it was at par with 40 kg ha^{-1} during both the years. Based on pooled value, increase in number of grains pod^{-1} due to 60 kg P_2O_5 ha^{-1} over 20 and 40 kg P_2O_5 ha^{-1} was 8.33 and 1.42 per cent, respectively (Table 4.9).

Sulphur: The data (Table 4.9) indicate that increased rate of sulphur from control to 20 kg ha^{-1} tended to significantly increase the number of grains pod^{-1} of chickpea but its further increase to 40 kg S ha^{-1} gave non-significant increase in grains pod^{-1} of chickpea during both the years and in pooled mean. The maximum grains pod^{-1} were recorded with the application of 40 kg S ha^{-1}. On pooled basis application of 40 kg S ha^{-1} brought about 6.77 and 0.71 per cent higher number of grains pod^{-1} over control and 20 kg S ha^{-1}, respectively.

Seaweed sap spray: Foliar application of seaweed saps significantly increased the number of grains pod^{-1} of chickpea over control during both the years as well as on pooled basis. Among seaweed saps foliar spray of *Kappaphycus* sap proved more effective in increasing number of pods plant^{-1} than *Gracilaria* sap. When compared with control (1.33 grains pod^{-1}) foliar application of *Kappaphycus* sap increased it significantly by 7.52 per cent and *Gracilaria* sap by 5.26 per cent on pooled basis (Table 4.9).

4.1.2.3 Grains plant^{-1}

Phosphorus: The maximum number of grains plant^{-1} were recorded under 60 kg P_2O_5 ha^{-1} which were significantly superior over control but at par with that of 40 kg P_2O_5 ha^{-1} in both the years of experimentation as well as on pooled basis. Data further reveal that application of 40 kg P_2O_5 ha^{-1} gave significantly higher number of grain plant^{-1} over 20 kg P_2O_5 ha^{-1} during both the years as well as on pooled basis. On pooled basis application of 40 and 60 kg P_2O_5 ha^{-1} increased grains plant^{-1} significantly by 17.97 and 20.98 per cent, respectively over 20 kg P_2O_5 ha^{-1} (Table 4.9).

Sulphur: An examination of data (Table 4.9) reveal that application of sulphur significantly increased the grains plant^{-1} of chickpea during both the years of study and on pooled mean basis. Application of 20 kg S ha^{-1} recorded significantly higher grains plant^{-1} over control were it was at par with 40 kg S ha^{-1}. Maximum mean number of grains plant^{-1} (54.97) were recorded by 40 kg S ha^{-1} which were 17.53 and 2.73 per cent higher over control and 20 kg S ha^{-1}, respectively.

Seaweed sap spray: Foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the number of grains plant^{-1} of chickpea over control during both the years of study and on pooled basis (Table 4.9). On pooled basis, minimum number of grains plant^{-1} (47.02) under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 16.08 and 14.10 per cent, respectively.

4.1.2.4 Grain yield plant^{-1}

Phosphorus: Compared to the application of 20 kg P_2O_5 ha^{-1}, an application of 40 kg P_2O_5 ha^{-1} significantly increased grain yield plant^{-1} of chickpea during two years of study and on pooled basis. The further increase in rate of P to 60 kg P_2O_5 ha^{-1} did not increase it significantly, however maximum grain yield $plant^{-1}$ of 6.54, 6.95 and 6.75 g $plant^{-1}$ was recorded during 2012-13, 2013-14 and on pooled basis with this treatment. On pooled basis application of 40 and 60 kg P_2O_5 ha^{-1} increased it significantly by 21.60 and 25.70 per cent, respectively over 20 kg P_2O_5 ha^{-1} (Table 4.9).

Sulphur: Compared to no sulphur, application of 20 kg S ha^{-1} brought about significant increase in grain yield $plant^{-1}$. The extent of increase being 11.03 and 16.82 per cent during the successive years. Sulphur application at 40 kg S ha^{-1} failed to exhibit significant effect in this respect in comparison to preceding sulphur rate. The trend of pooled result was different than yearly response, wherein 0 to 20 and 20 to 40 kg S ha^{-1} tended to produce 14.11 and 4.07 per cent higher grain yield $plant^{-1}$ which is of significant order (Table 4.9).

Seaweed sap spray: An examination of data (Table 4.9) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the grain yield $plant^{-1}$ of chickpea during both the years of study as well as on pooled basis. However, both the seaweeds recorded the yield at par to each other. On pooled basis lowest grain yield of 5.58 g $plant^{-1}$ was recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 17.56 and 16.49 per cent, respectively over the control.

Interaction effect of phosphorus and sulphur: It is clear from the data (Table 4.11) that interaction effect was significant with respect to grain yield $plant^{-1}$ of chickpea during both the years and on pooled basis. During 2012-13 at P_{20} and P_{40} there was no significant effect of various doses of S on grain yield $plant^{-1}$. However at P_{60}, the grain yield $plant^{-1}$ was statistically higher at S_{40} as compared to control but it was at par with S_{20}. At S_0 the crop responded up to P_{40}. At S_{20} the response was up to P_{60} and at S_{40} the crop responded up to P_{60} but P_{40} and P_{60} were statistically at par with respect to grain yield $plant^{-1}$. During 2013-14 at P_{20} there was no significant effect up to S_{20}. Maximum grain yield $plant^{-1}$ was recorded with combined application of $P_{60}S_{20}$ (7.31 g $plant^{-1}$). On pooled basis, at P_{20} significant response observed by maximum level of S at 40 kg ha^{-1}, whereas, at P_{40} and P_{60} grain yield $plant^{-1}$ higher with S_{20} over S_0, but the response was at par with S_{40}.combined application of phosphorus at 60 kg ha^{-1} with sulphur at 40 kg ha^{-1} recorded maximum grain yield $plant^{-1}$ (7.23 g) that was at par with other combinations of phosphorus at 60 kg ha^{-1} with sulphur at 20 kg ha^{-1} and phosphorus at 40 kg with sulphur at 40 kg under test (Table 4.11).

Table 4.11. Interaction effect of phosphorus and sulphur on grain yield $plant^{-1}$

Treatment	Grain yield $plant^{-1}$ (g)								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	5.17	5.48	5.67	4.96	5.05	5.87	5.07	5.27	5.77
P_{40}	6.17	6.32	6.71	5.54	7.24	7.19	5.85	6.78	6.95
P_{60}	5.53	6.92	7.16	6.25	7.31	7.30	5.89	7.12	7.23
S.Em.±	0.19			0.19			0.14		
CD (P=0.05)	0.57			0.58			0.39		

4.1.2.5 100-grain weight

Phosphorus: Over the years of investigation and also in pooled mean, increasing levels of phosphorus fertilization at 20 to 40 kg P_2O_5 ha^{-1} gave significantly higher 100-grain weight. The grain weight at 60 kg P_2O_5 ha^{-1} remained at par with 40 kg P_2O_5 ha^{-1}. On pooled basis, the increase in 100 grain weight was to the tune of 4.38 and 1.89 per cent by increasing phosphorus levels from 20 to 40 and 40 to 60 kg ha^{-1}, respectively (Table 4.9).

Sulphur: It is apparent from the data (Table 4.9) that sulphur application was effective in increasing 100-grain weight of chickpea. Pooled analysis revealed significant increase in 100-grain weight with application of 40 kg S ha^{-1} by 4.70 and 1.12 per cent over control and 20 kg ha^{-1}, respectively. However, 20 and 40 kg S ha^{-1} recorded at par values.

Seaweed sap spray: Data (Table 4.9) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the 100-grain weight of chickpea during both the years of study as well as on pooled basis. Further analysis of pooled data revealed that 100-grain weight of 13.72 g recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 7.29 and 3.13 per cent, respectively.

4.1.3 YIELD AND HARVEST INDEX

4.1.3.1 Grain yield

Phosphorus: The grain yield of chickpea was significantly influenced by phosphorus fertilization. The yield increased significantly with successive increase in rate of phosphorus application from 20 to 40 kg ha^{-1} in each year of study and on pooled data basis. The increase in yield by applying 60 P_2O_5kg ha^{-1} associated with non-significant increase over 40 kg P_2O_5 ha^{-1}. The trends of pooled grain yield in response to phosphorus application show a significant increase of 10.76 and 14.39 per cent over 20 kg P_2O_5 ha^{-1} by applying 40 and 60 kg P_2O_5 ha^{-1} (Table 4.12).

Sulphur: The data (Table 4.12) indicate that application of 20 kg S ha^{-1} showed statistical superiority over control and was found at par with 40 kg S ha^{-1} in producing grain yield across the years. Pooled data show that application of sulphur up to 40 kg S ha^{-1} tended to increase grain yield of chickpea significantly over 20 kg S ha^{-1} and control. Pooled mean shows that application of 40 kg S ha^{-1} resulted in significantly higher grain yield (1546 kg ha^{-1}) by a margin of 22.99 and 3.83 per cent over control and 20 kg S ha^{-1}.

Seaweed sap spray: Data (Table 4.12) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps increased the grain yield of chickpea significantly. However, both the seaweeds recorded statistically similar grain yield during both the years and on pooled basis. When compared with pooled grain yield of 1303 kg ha^{-1} recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 15.96 and 13.43 per cent, respectively.

Interaction effect of phosphorus and sulphur: It is clear from the data presented in Table 4.13 that interaction effect of phosphorus and sulphur on grain yield of chickpea was found to be significant in both the years and in pooled mean. During 2012-13 at P_{20} grain yield was significantly increased with increase in sulphur dose up to 40 kg ha^{-1}. Whereas, at P_{40} the significant response was only up to sulphur 20 kg ha^{-1} and further increase in dose of sulpur to S_{40} failed to observed significant improvement in grain yield. However, at P_{60}, there was no significant effect of various sulphur doses on grain yield. At S_0 and S_{20} the crop responded up to P_{40}. At S_{40} there was no response of various phosphorus doses. Similar, response was recorded during 2013-14. On pooled basis at P_{20} the grain yield was significantly increased with increase in sulphur dose up to 40 kg ha^{-1}. Similarly, at S_0 each increase in phosphorus up to P_{60} significantly increased the grain yield. Combined application of phosphorus at 60 kg ha^{-1} with sulphur at 40 kg ha^{-1} recorded maximum grain yield (1558 kg ha^{-1}) which was at par with $P_{60}S_{20}$, $P_{40}S_{40}$, $P_{40}S_{20}$ and $P_{20}S_{40}$. However, at no sulphur each increase in phosphorus up to 60 kg ha^{-1} significantly increased the grain yield and at

20 kg phosphorus each increase in sulphur significantly increased in grain yield up to 40 kg S ha^{-1} (Table 4.13).

Table 4.13. Interaction effect of phosphorus and sulphur on grain yield

Treatment	Grain yield (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	1077	1370	1524	1015	1389	1546	1046	1379	1535
P_{40}	1285	1526	1533	1326	1547	1555	1305	1536	1544
P_{60}	1410	1536	1542	1430	1567	1574	1420	1552	1558
S.Em.±	44			43			31		
CD (P=0.05)	132			130			89		

4.1.3.2 Haulm yield

Phosphorus: The application of increasing levels of phosphorus increased the haulm yield of chickpea. Application of 40 kg P_2O_5 ha^{-1} showed statistical superiority over 20 kg P_2O_5 ha^{-1}, but remained at par with 60 kg P_2O_5 ha^{-1} in producing haulm yield across the years and on pooled basis. The maximum haulm yield (2878, 2826 and 2852 kg ha^{-1} during 2012-13, 2013-14 and pooled data) obtained when phosphorus applied at 60 kg ha^{-1}. On pooled basis increase in haulm yield with the application of 40 and 60 kg P_2O_5 ha^{-1} were 10.93 and 14.58 per cent over 20 kg P_2O_5 ha^{-1}, respectively (Table 4.12).

Sulphur: An evaluation of data (Table 4.12) show that application of sulphur significantly enhanced the haulm yield of chickpea. Application of 20 kg S ha^{-1} recorded significantly higher haulm yield over control, but it was statistically at par with 40 kg S ha^{-1} across the year. The maximum haulm yield (2944, 2896 and 2920 kg ha^{-1} during 2012-13, 2013-14 and pooled data) recorded by 40 kg S ha^{-1}. Pooled figures show that application of 40 kg S ha^{-1} recorded 23.21 and 3.80 per cent higher haulm yield over control and 20 kg S ha^{-1}, respectively.

Seaweed sap spray: Foliar application of seaweed saps recorded significantly higher haulm yield than water spray during both the years and on pooled basis (Table 4.12). Maximum haulm yield was recorded with application of *Kappaphycus* sap but it was statistically at par with application of *Gracilaria* sap during both the years of study as well as on pooled basis. When compared with pooled haulm yield of 2456 kg ha^{-1}

recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 16.25 and 13.64 per cent, respectively.

Interaction effect of phosphorus and sulphur: It is clear from data presented in Table 4.14 that interaction effect of phosphorus and sulphur on haulm yield of chickpea was significant during both the years and on pooled basis. During 2012-13 at P_{20} the haulm yield was significantly increased with increase in sulphur dose up to 40 kg ha^{-1}. However, at P_{40} and P_{60}, there was significant increase in haulm yield up to S_{20}. At S_0 and S_{20} the crop responded up to P_{40}. At S_{40} there was no response of various phosphorus doses. Similar, response was also recorded during 2013-14 and on pooled basis. On pooled basis, combined application of phosphorus at 60 kg ha^{-1} with sulphur at 40 kg ha^{-1} recorded maximum haulm yield (2943 kg ha^{-1}) it was at par with $P_{60}S_{20}$, $P_{20}S_{40}$, $P_{40}S_{20}$ and $P_{40}S_{40}$. However, at no sulphur increase in each level of phosphorus up to 60 kg ha^{-1} significantly increased the haulm yield and at 20 kg phosphorus increase in each level of sulphur significantly increased the haulm yield up to 40 kg S ha^{-1}, while at S_{40} haulm yield of chickpea not responded to P application (Table 4.14).

Table 4.14. Interaction effect of phosphorus and sulphur on haulm yield

Treatment	Haulm yield (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	1869	2622	2920	2055	2589	2878	1962	2605	2899
P_{40}	2502	2922	2938	2429	2882	2896	2465	2902	2917
P_{60}	2700	2961	2974	2664	2901	2913	2682	2931	2943
S.Em.±	84			82			59		
CD (P=0.05)	253			247			170		

4.1.3.3 Biological yield

Phosphorus: The biological yield of chickpea was significantly improved by applying phosphorus from 20 to 40 kg P_2O_5 ha^{-1} but further increase from 40 to 60 kg ha^{-1} remained at par to 40 kg P_2O_5 ha^{-1} during both the years of study as well as pooled basis. Pooled data show that application of 40 and 60 kg P_2O_5 ha^{-1} associated with gain in biological yield by 10.87 and 14.52 per cent over 20 kg P_2O_5 ha^{-1}, respectively (Table 4.12).

Sulphur: The data (Table 4.12) are indicative of the statistical superiority of 20 kg S ha^{-1} in producing biological yield over control. The maximum biological yield was recorded under 40 kg S ha^{-1} but it remained at par with 20 kg S ha^{-1} across the years. Pooled mean shows that application of 40 kg S ha^{-1} resulted in significantly higher biological yield to the tune of 23.14 and 3.79 per cent over control and 20 kg S ha^{-1}, respectively.

Seaweed sap spray: The data (Table 4.12) reveal that foliar application of seaweed saps significantly increased the biological yield of chickpea over control. Maximum biological yield (4371, 4361 and 4366 kg ha^{-1}) during 2012-13, 2013-14 and pooled data was recorded with the application of *Kappaphycus* sap which was statistically at par with application of *Gracilaria* sap during both the years of study as well as on pooled basis. When compared with two year pooled data, application of *Kappaphycus* and *Gracilaria* saps increased biological yield significantly by 16.15 and 13.57 per cent, respectively over recorded under control (3759 kg ha^{-1}).

Interaction effect of phosphorus and sulphur: Data (Table 4.15) on interaction effect of phosphorus and sulphur on biological yield found significant during both the years and on pooled basis. During 2012-13 at P_{20} the biological yield was significantly increased with increase in sulphur dose up to 40 kg ha^{-1}. However, at P_{40} and P_{60}, there was significant increase in biological yield only up to S_{20}. At S_0 and S_{20} the crop responded up to P_{40}. At S_{40} there was no response recorded to various phosphorus doses. Similarly, during 2013-14 at P_{20} the biological yield was significantly increased with increase in sulphur dose up to 40 kg ha^{-1}. At P_{40} and P_{60}, there was significant increase in biological yield up to S_{20}. On pooled basis, similar trends of P and S levels aws observed as that of 2013-14. However, combined application of phosphorus at 60 kg ha^{-1} with sulphur at 40 kg ha^{-1} recorded maximum biological yield (4501 kg ha^{-1}) and it was at par with $P_{60}S_{20}$, $P_{40}S_{20}$, $P_{40}S_{40}$ and $P_{20}S_{40}$ and significantly superior over rest of treatments combinations.

Table 4.15. Interaction effect of phosphorus and sulphur on biological yield

Treatment	Biological yield (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	2946	3991	4444	3069	3977	4424	3007	3984	4434
P_{40}	3786	4448	4471	3754	4429	4451	3770	4438	4461
P_{60}	4109	4497	4516	4094	4469	4487	4102	4483	4501
S.Em.±	121			116			84		
CD (P=0.05)	364			349			242		

4.1.3.4 Harvest index

Harvest index of chickpea crop remained unaffected by phosphorus, sulphur and seaweed sap application (Table 4.12).

4.1.4 Quality parameters

4.1.4.1 Total protein content in grain

Phosphorus: An evaluation of the data (Table 4.16) reveal the fact that protein content increased significantly with increasing levels of phosphorus. Application of phosphorus at 40 kg P_2O_5 ha^{-1} significantly influenced the protein content of chickpea grain over 20 kg P_2O_5 ha^{-1}, but it remained at par with further increase in phosphorus level to 60 kg ha^{-1} during both the years and on pooled basis. On pooled basis, soil enrichment with 40 kg P_2O_5 ha^{-1} significantly increased the protein content of grain by 3.97 per cent over 20 kg P_2O_5 ha^{-1}. However, further addition of phosphorus, i.e., 60 kg P_2O_5 ha^{-1} increased the protein content, but the magnitude of increase was not significant.

Sulphur: It was found that increasing sulphur levels from control to 40 kg S ha^{-1} progressively increased the protein content of chickpea. The maximum protein content was recorded with application of 40 kg S ha^{-1}, results of which were at par with 20 kg S ha^{-1} during both the years and in pooled mean. On pooled basis application of 20 and 40 kg S ha^{-1} was associated with 4.27 and 5.22 per cent higher protein content over control, respectively (Table 4.16).

Seaweed sap spray: The data (Table 4.16) reveal that foliar application of seaweed saps significantly increased the protein content of chickpea during both the years and on pooled basis. Pooled data further reveal that protein content of 21.12 per cent was recorded under control, while application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 4.92 and 3.69 per cent, respectively.

4.1.4.2 Amino acids

4.1.4.2.1 Methionine

Phosphorus: The data (Table 4.16) show that the phosphorus application failed to influences significantly methionine content of chickpea.

Sulphur: Methionine content of chickpea grains increased significantly with the increasing levels of sulphur application up to 40 kg ha^{-1} during both the years of investigation as well as on pooled basis (Table 4.16). Pooled figures point out 15.00 and 7.48 per cent higher methionine content in chickpea grains over control and 20 kg S ha^{-1} with application of 40 kg S ha^{-1}, respectively.

Seaweed sap spray: The data (Table 4.16) reveal that foliar application of *Kappaphycus* sap significantly increased the methionine content of chickpea during both the years of study as well as on pooled basis. When compared with pooled methionine content of 1.00 g $16g^{-1}$ N recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 13.00 and 8.00 per cent, respectively.

4.1.4.2.2 Cysteine

Phosphorus: No significant change in cysteine content in chickpea grains was recorded by phosphorus application (Table 4.16).

Sulphur: The data presented in Table 4.16 show that the cysteine content of chickpea grains increased significantly with application of increasing levels of sulphur up to 40 kg ha^{-1} during both the years of investigation as well as on pooled basis. Data pooled over two seasons reveal that application of 40 kg S ha^{-1} increased cysteine content significantly by 15.38 and 8.11 per cent over control.

Seaweed sap spray: The data (Table 4.16) reveal that foliar application of seaweed saps significantly increased the cysteine content of chickpea during both the years of study as well as on pooled basis over control. On pooled basis, application of *Kappaphycus* and *Gracilaria* saps increased the cysteine content significantly by 9.43 and 6.60 per cent, respectively over control (1.06 g 16 g N^{-1}). Maximum cysteine content observed by *Kappaphycus* sap spray, was significantly superior over *Gracilaria* sap for the year 2012-13, 2013-14 and on pooled basis.

4.1.4.2.3 Cystine

Phosphorus: No significant effect was observed due to phosphorus application on cystine content in chickpea (Table 4.16).

Sulphur: The data (Table 4.16) reveal that cystine content of chickpea grains increased significantly with increasing levels of sulphur during both the years of study and on pooled basis. When pooled data was compared, cystine contents of 0.98 g 16 g^{-1} N was recorded under control, while application of 20 and 40 kg S ha^{-1} increased it significantly by 7.14 and 11.22 per cent, respectively over control.

Seaweed sap spray: The data (Table 4.16) further reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the cystine content in chickpea grains during both the years of experimentation and as well as on pooled basis. When compared with pooled cystine content of 0.99 g $16g^{-1}$ N recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 9.09 and 6.06 per cent, respectively.

4.2 BIOCHEMICAL ANALYSIS

4.2.1 Chlorophyll content of leaves at 60 DAS

Phosphorus: The data (Table 4.17) show that there was significant increase in chlorophyll content of chickpea leaves which obtained by raising phosphorus level over a range of 20-60 kg ha^{-1} across the years and in pooled mean except during second year where 40-60 kg ha^{-1} recorded statistically at par result. Pooled data on chlorophyll content indicate that the application of 60 kg P_2O_5 ha^{-1} was associated with its 28.65 and 2.92 per cent increase over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: Over the years and in pooled mean, sulphur fertilization up to 40 kg S ha^{-1} gave significantly higher chlorophyll content in leaves of chickpea at 60 DAS. The pooled data also reveal that the increase in chlorophyll content due to 40 kg S ha^{-1} was to the tune of 37.16 and 2.45 per cent, respectively over control and 20 kg S ha^{-1}. (Table 4.17).

Seaweed sap spray: The data (Table 4.17) reveal that foliar application of seaweed saps increased significantly the chlorophyll content in chickpea leaves at 60 DAS during both the years and in pooled mean. Pooled data on chlorophyll content indicate that the foliar application of *Kappaphycus* sap resulted in 36.56 and 6.72 per cent increase over control and foliar application of *Gracilaria* sap, respectively.

4.2.2 Nutrient content

4.2.2.1 Nitrogen

Leaves at 60 DAS

Phosphorus: Data Table 4.18 that the N content of chickpea leaves at 60 DAS was significantly increased by raising P levels over a range of 20 to 40 kg P_2O_5 ha^{-1}, but its further increase from 40 to 60 kg ha^{-1} did not increase N content significantly during both the years of experimentation. Pooled data show that application of 60 kg P_2O_5 ha^{-1} significantly increased the N content in leaves at 60 DAS by 11.91 and 0.81 per cent over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: The data presented in Table 4.18 reveal that application of sulphur also increased N content of leaves at 60 DAS. Maximum N content was recorded with 40 kg S ha^{-1} which was at par with 20 kg during 2013-14 and significantly superior during 2012-13. Data pooled over two seasons reveal that application of sulphur at 20 kg ha^{-1} significantly increased the N content over control, but further increase in dose of sulphur to 40 kg ha^{-1} failed to increase N content of leaf at 60 DAS. On pooled basis, minimum N content (3.152 per cent) recorded under control application of 20 and 40 kg S ha^{-1} increased it significantly by 8.72 and 9.55 per cent, respectively.

Seaweed sap spray: The data (Table 4.18) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the N content in chickpea leaves at 60 DAS during both the years of experimentation as well as on pooled basis. On pooled basis, N content of 3.093 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 13.77 and 10.60 per cent, respectively.

Grain

Phosphorus: The information given in Table 4.18 that the N content in chickpea grain significantly increased by raising P levels from 20 to 40 kg P_2O_5 ha^{-1}, but further increase in it from 40 to 60 kg ha^{-1} did not increase the N content significantly during both the years of experimentation and on pooled basis. Pooled data show that with the application of 40 and 60 kg P_2O_5 ha^{-1} significantly increased the N content of grain by 3.96 and 4.23 per cent over 20 kg P_2O_5 ha^{-1}, respectively.

Sulphur: The data presented in Table 4.18 reveal that application of sulphur increased the N content in grain of chickpea. Maximum N content was recorded under 40 kg S ha^{-1}. However it was at par with 20 kg S ha^{-1} during both the years and on pooled basis. On pooled basis application of 20 and 40 kg S ha^{-1} recorded 4.24 and 5.19 per cent higher N content over control, respectively.

Seaweed sap spray: The data (Table 4.18) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the N content in chickpea grain during both the years of experimentation as well as on pooled basis. Pooled data reveal that N content of 3.379 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 4.91 and 3.73, respectively.

Haulm

Phosphorus: Data Table 4.18 show that the N content in haulm significantly increased by raising P level from 20 to 40 kg P_2O_5 ha^{-1} but the further increase in P dose from 40 to 60 kg ha^{-1} did not increase it significantly during both the years of experimentation and on pooled basis. Pooled data show that with the application of 40 and 60 kg P_2O_5 ha^{-1}, N content in haulm significantly increased by 11.13 and 11.40 per cent over 20 kg P_2O_5 ha^{-1} (0.728 per cent), respectively.

Sulphur: The data presented in Table 4.18 reveal that application of sulphur increased the N content in haulm significantly. Maximum N content was recorded under application of 40 kg S ha^{-1} and it was at par with the values obtained in dose of 20 kg S ha^{-1} during both the years and on pooled basis. On pooled mean basis, N contents of 0.747 per cent recorded under control, application of 20 and 40 kg S ha^{-1} increased it significantly by 7.10 and 7.36 per cent, respectively.

Seaweed sap spray: The data of Table 4.18 reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the N content in haulm during both the years of experimentation and on pooled basis. However, both the seaweed saps recorded at par values during 2012-13 and on pooled basis however, it was significantly superior during 2013-14. On pooled basis, N content of 0.730 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 11.51 and 10.14 per cent, respectively.

4.2.2.2 Phosphorus

Leaves at 60 DAS

Phosphorus: An assessment of data presented in Table 4.19 indicate that P content of leaves at 60 DAS increased significantly by increasing phosphorus levels from control to 60 kg P_2O_5 ha^{-1}. Pooled data show that maximum P content (0.462 per cent) of leaves at 60 DAS was observed with 60 kg P_2O_5 ha^{-1}, which was significantly superior over 40 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1} by 2.90 and 5.24 per cent, respectively.

Sulphur: An application of sulphur significantly increased P content of leaves at 60 DAS. Increasing levels of sulphur up to 40 kg S ha^{-1} increased the P content significantly but remained at par with 20 kg S ha^{-1}. Compared to P content of 0.436 per cent recorded under unfertilized control, application of 20 and 40 kg S ha^{-1} increased it significantly by 4.59 and 5.05 per cent, respectively (Table 4.19).

Seaweed sap spray: The data (Table 4.19) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the P content of leaves (60 DAS) during both the years of experimentation and on pooled basis. On pooled basis Compared to P content of 0.438 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 4.34 and 3.65 per cent, respectively.

Grain

Phosphorus: An assessment of data Table 4.19 indicates that P content of grain increased significantly by increasing phosphorus levels up to 60 kg P_2O_5 ha^{-1} during both the years and on pooled basis. Pooled data showed that with the application of 60 kg P_2O_5 ha^{-1}, P content in grain as raised by 7.21 and 2.88 per cent over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: Application of sulphur up to 40 kg ha^{-1} significantly increased the P content in grain. However, during 2013-14 it was at par with application of 20 kg S ha^{-1}. Data pooled over two seasons reveal that application of sulphur up to 40 kg ha^{-1} increased the P content with each level significantly. On pooled basis, when compared with phosphorus contents of 0.334 per cent recorded under unfertilized control, application of 20 and 40 kg S ha^{-1} increased it significantly by 3.59 and 6.59 per cent, respectively (Table 4.19).

Seaweed sap spray: The data (Table 4.19) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the P content of chickpea grain during both the years of experimentation and on pooled basis. However, both the seaweed saps were par with each other during both the years and on pooled basis. On pooled basis, phosphorus content of 0.328 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 8.23 and 7.62 per cent, respectively.

Haulm

Phosphorus: A perusal of data in Table 4.19 indicate that P content of haulm increased significantly up to 60 kg ha^{-1} during both the years and on pooled basis. Pooled data show that with application of 60 kg P_2O_5 ha^{-1} increased the P content by 7.51 and 2.69 per cent over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: Application of sulphur significantly increased the P content of haulm of chickpea. The data further reveal that maximum P content was recorded with application of 40 kg S ha^{-1}. However, it was at par with 20 kg S ha^{-1} during both the years and on pooled basis. On pooled basis, 20 and 40 kg S ha^{-1} recorded 4.67 and 5.61 per cent higher P content over control, respectively (Table 4.19).

Seaweed sap spray: Foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the P content of haulm during both the years of experimentation and on pooled basis. However, both the seaweed saps were at par with each other during both the years and on pooled basis. Compared with P content of 0.210 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 8.57 and 8.10 per cent, respectively (Table 4.19).

4.2.2.3 Potassium

Leaves at 60 DAS

Phosphorus: Over the year of study K content of leaves (60 DAS) increased significantly with increasing levels of phosphorus up to 60 kg P_2O_5 ha^{-1}. However, it remained at par with 40 kg P_2O_5 ha^{-1}. On pooled basis, K content in leaves at 60 DAS increased by 6.07 and 7.15 per cent with the application of 40 and 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1}, respectively (Table 4.20).

Sulphur: Application of sulphur at 20 kg ha^{-1} significantly increased the K content of leaves at 60 DAS over control while, further increase in sulphur level to 40 kg ha^{-1} it was at par with 20 kg S ha^{-1} during both the years of experimentations as well as on pooled basis. Maximum K content was recorded with 40 kg S ha^{-1} which was at par with 20 kg S ha^{-1}. When compared with K content of 2.258 per cent recorded under unfertilized control, application of 20 and 40 kg S ha^{-1} increased it significantly by 9.61 and 10.36 per cent, respectively (Table 4.20).

Seaweed sap spray: The data (Table 4.20) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the K content in chickpea leaves at 60 DAS. However, both the seaweed saps were at par to each other during both the years of experimentation and on pooled basis. On pooled basis, when compared with K content of 2.297 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 7.36 and 7.18 per cent, respectively.

Grain

Phosphorus: Increasing levels of phosphorus up to 60 kg P_2O_5 ha^{-1} significantly increased the K content in grain during 2012-13 and on pooled basis while, during 2013-14 it was at par with 40 kg P_2O_5 ha^{-1}. On pooled basis, K content increase by 4.91 and 10.28 per cent with the application of 40 and 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1}, respectively (Table 4.20).

Sulphur: Application of sulphur significantly increased the K content in grain. The maximum K content was recorded with application of 40 kg S ha^{-1} which remained at par with 20 kg S ha^{-1} application during both the years of experimentation as well as on pooled basis. On pooled basis when compared with K content of 0.599 per cent recorded under control, application of 20 and 40 kg S ha^{-1} increased it significantly by 15.69 and 16.86 per cent, respectively (Table 4.20).

Seaweed sap spray: The data (Table 4.20) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the K content in chickpea grain. However, both the seaweed saps were at par to each other during both the years of experimentation and on pooled basis. Pooled data further reveal that K content of

0.612 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 12.91 and 12.58, respectively.

Haulm

Phosphorus: Over the year of study K content of haulm increased significantly with increasing levels of phosphorus up to 60 kg P_2O_5 ha^{-1}. Maximum K content was obtained with 60 kg P_2O_5 ha^{-1} however, it was at par with 40 kg P_2O_5 ha^{-1} during both the years and on pooled basis. On pooled basis, K content of haulm increased by 5.03 and 6.27 per cent with the application of 40 and 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1}, respectively (Table 4.20).

Sulphur: Sulphur application significantly increased the K content of chickpea haulm. The maximum K content was recorded with the application of 40 kg S ha^{-1} but it remained at par with 20 kg S ha^{-1} during both the years as well as on pooled basis. On pooled basis when compared with K content of 1.742 per cent recorded under control, application of 20 and 40 kg S ha^{-1} increased it significantly by 14.58 and 15.84 per cent, respectively (Table 4.20).

Seaweed sap spray: The data (Table 4.20) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the K content of haulm. However, both the seaweed saps recorded at par during both the years and on pooled basis. Two years pooled K content of 1.786 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 11.59 and 10.64 per cent, respectively.

4.2.2.4 Sulphur

Leaves at 60 DAS

Phosphorus: It is apparent from data (Table 4.21) that S content in leaves of chickpea (at 60 DAS) increased significantly due to phosphorus application. Maximum S content was recorded under 60 kg P_2O_5 ha^{-1} but, it was at par with 40 kg P_2O_5 ha^{-1} during both the years as well as on pooled basis. Pooled analysis indicates that application of 40 and 60 kg P_2O_5 ha^{-1} resulted in 6.06 and 7.07 per cent higher S content over 20 kg P_2O_5 ha^{-1}, respectively.

Sulphur: It is clear from data (Table 4.21) that enhancing S level from control to 40 kg ha^{-1} was significantly effective in improving S concentration of chickpea leaves

(60 DAS) during both the years and on pooled basis. However, 40 kg was at par S content to 20 kg S ha^{-1} application during both the years and on pooled basis. On pooled basis when compared with S content of 0.195 per cent recorded under control, application of 20 and 40 kg S ha^{-1} increased it significantly by 8.21 and 9.74, respectively.

Seaweed sap spray: The data (Table 4.21) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the S content in chickpea leaves at 60 DAS during both the years and on pooled basis. The results of two years pooled reveal that S content of 0.197 per cent recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 7.61 and 7.11 per cent, respectively.

Grain

Phosphorus: It is apparent from the contents of Table 4.21 that S content of chickpea grain increased significantly due to phosphorus application. Maximum S content was recorded under 60 kg P_2O_5 ha^{-1} but it was at par with 40 kg P_2O_5 ha^{-1} during both the years of experimentation as well as on pooled basis. Pooled data indicate that application of 40 and 60 kg P_2O_5 ha^{-1} was associated 9.34 and 10.99 per cent higher S content over 20 kg P_2O_5 ha^{-1}, respectively.

Sulphur: The data (Table 4.21) indicate that enhancing of S levels over a range of control to 40 kg ha^{-1} was significantly effective in improving S concentration in chickpea grain during both the years and on pooled basis. Pooled data further indicate that when compared with S content of 0.178 per cent recorded under control, application of 20 and 40 kg S ha^{-1} increased it significantly by 11.80 and 15.73 per cent, respectively.

Seaweed sap spray: The data (Table 4.21) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the S content in chickpea grain during both the years and on pooled basis. S content of 0.184 per cent recorded under control, application of *Kappaphycus* sap increased it significantly by 8.70 per cent and *Gracilaria* sap by 7.61 per cent.

Haulm

Phosphorus: It is apparent from data (Table 4.21) that S content in haulm of chickpea increased significantly due to phosphorus application. Maximum S content was recorded with application of 60 kg P_2O_5 ha^{-1} but it was at par with 40 kg P_2O_5 ha^{-1} during both the years as well as on pooled basis. Pooled data show that application of 60 kg P_2O_5 ha^{-1} was associated with 5.71 and 7.14 per cent higher S content as compared to application of 40 and 20 kg P_2O_5 ha^{-1}, respectively.

Sulphur: It is clear from data (Table 4.21) that enhancing of S levels from control to 40 kg ha^{-1} was significantly effective in improving S concentration of chickpea haulm during both the years and on pooled basis. Pooled over two years results indicate that compared with S content of 0.069 per cent recorded under control, application of 20 kg S ha^{-1} increased it significantly by 7.25 per cent and 40 kg S ha^{-1} by 11.59 per cent.

Seaweed sap spray: The data (Table 4.21) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the S content in chickpea haulm during both the years of experimentation and on pooled basis. However, both the seaweed saps were at par with each other during both the years and on pooled basis. Compared with S content of 0.070 per cent recorded under control, application of *Kappaphycus* sap increased it significantly by 7.14 per cent.

4.2.3 Nutrient uptake

4.2.3.1 Nitrogen

Grain

Phosphorus: The data reveal significantly higher N uptake by chickpea grain with successive increase in P dose from 20 to 40 kg P_2O_5 ha^{-1}, but further increase from 40 to 60 kg P_2O_5 ha^{-1} remained at par with 40 kg P_2O_5 ha^{-1} over the years of study and also on pooled mean basis. On pooled basis, enhancing of phosphorus dose from 20-40 and 40-60 kg ha^{-1} were associated with 14.00 and 3.38 per cent increased N uptake, respectively (Table 4.22 and Fig. 4.2).

Sulphur: Over the years data show that N uptake by chickpea grain was significantly increased with increasing S level from control to 20 kg ha^{-1}, but further increase to 40 kg ha^{-1} remained at par with 20 kg S ha^{-1} during both the years. On pooled basis increasing levels of sulphur up to 40 kg ha^{-1} significantly increased N uptake. Pooled data indicate that application of 40 kg S ha^{-1} resulted in increase of 28.11 and 4.68 per cent N uptake over control and 20 kg S ha^{-1}, respectively (Table 4.22 and Fig. 4.2).

Seaweed sap spray: The data (Table 4.22 and Fig. 4.2) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the N uptake by chickpea grain during both the years of experimentation and as well as on pooled basis. Compared to pooled N uptake of 44.30 kg ha^{-1} recorded under control, application of *Kappaphycus* sap increased it significantly by 21.69 per cent and *Gracilaria* sap by 16.91 per cent.

Interaction effect of phosphorus and sulphur: It was found that increasing levels of phosphorus (20-60 kg P_2O_5 ha^{-1}) and sulphur (0-40 kg S ha^{-1}) levels progressively increased the N uptake by grain during both the year and on pooled basis. On pooled basis different levels of phosphorus in absence of sulphur significantly increased N uptake by grain from 20 to 60 kg P_2O_5 ha^{-1}. But when it was combined with sulphur at 20 kg ha^{-1}, it significantly increased N accumulation in chickpea grain up to 40 kg P_2O_5 ha^{-1}. Further, at S_{40} addition of phosphorus did not prove effect on N uptake by grain. At S_0 and S_{20}, N uptake by grain significantly increased with P levels, but response of Phosphorus application not observed significantly with $S_{40.}$ However, maximum N uptake (56.03 kg ha^{-1}) by grain was recorded with $P_{20}S_{40}$ which was at par with $P_{40}S_{20}$, $P_{40}S_{40}$, $P_{60}S_{20}$ and $P_{60}S_{40}$. (Table 4.23 and Fig. 4.2).

Table 4.23. Interaction effect of phosphorus and sulphur on N uptake by grain

Treatment	N uptake grain (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	33.64	45.32	56.39	32.06	48.13	55.67	32.85	46.73	56.03
P_{40}	44.66	54.33	54.41	44.76	55.49	55.51	44.71	54.91	54.96
P_{60}	49.54	56.20	52.77	52.13	54.80	54.20	50.83	55.50	53.49
S.Em.±	1.68			1.57			1.15		
CD (P=0.05)	5.04			4.70			3.31		

Haulm

Phosphorus: The data reveal significantly higher N uptake by haulm with successive increase in P dose from 20 to 40 kg P_2O_5 ha^{-1}, but further increase of dose from 40 to 60 kg P_2O_5 ha^{-1} remained at par with 40 kg P_2O_5 ha^{-1} during both the years and on pooled mean. Enhancing of phosphorus dose from 20-40 and 40-60 kg ha^{-1} associated with 21.24 and 3.39 per cent increase in N uptake, respectively (Table 4.22 and Fig. 4.2).

Sulphur: Over the years data show that N uptake by haulm increase significantly by increasing S level from control to 20 kg ha^{-1}, but further increase to 40 kg ha^{-1}

remained at par with 20 kg S ha^{-1}. However, on pooled basis increasing levels of sulphur from control to 40 kg ha^{-1} significantly increased N uptake in haulm. Pooled analysis indicates that application of 40 kg S ha^{-1} resulted in increase of 29.74 and 4.03 per cent higher N uptake by over control and 20 kg S ha^{-1}, respectively (Table 4.22 and Fig. 4.2).

Seaweed sap spray: The data (Table 4.22 and Fig. 4.2) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the N uptake by haulm during both the years of experimentation and on pooled basis. However, during individual years both the seaweeds were at par but on pooled basis *Kappaphycus* sap was significantly superior over *Gracilaria* sap. When compared with pooled N uptake of 18.25 kg ha^{-1} recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 27.84 and 23.51 per cent, respectively.

Interaction effect of phosphorus and sulphur: Combined application of phosphorus and sulphur levels had significant effect on N uptake by haulm in both the years and in pooled mean. When compared on pooled mean basis, different levels of phosphorus in absence of sulphur significantly increased N uptake by haulm from 20 to 60 kg P_2O_5 ha^{-1}. But when it was combined with sulphur at 20 kg ha^{-1}, it significantly increased N accumulation by chickpea haulm up to 40 kg P_2O_5 ha^{-1}. Whereas, at P_{60} N uptake by haulm was significantly superior at S_{20} over S_0 but at par with S_{40}. At S_0, N upatkae increased significantly up to P_{60} but at S_{20} and S_{40} response observed up to P_{40} and further increase in phosphorus level to P_{60} failed to get significant response. Maximum N uptake (24.33 kg ha^{-1}) by haulm was recorded by combined application of P_2O_5 at 60 kg ha^{-1} and S at 40 kg ha^{-1} which was at par with $P_{60}S_{20}$, $P_{40}S_{20}$ and $P_{40}S_{40}$ (Table 4.24).

Table 4.24. Interaction effect of phosphorus and sulphur on N uptake by haulm

Treatment	N uptake haulm (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	12.10	20.28	22.65	13.60	19.66	22.74	12.85	19.97	22.70
P_{40}	20.38	24.03	24.21	19.48	23.93	22.57	19.93	23.98	23.39
P_{60}	22.76	24.01	24.20	20.24	23.44	24.47	21.50	23.73	24.33
S.Em.±	0.67			0.65			0.47		
CD (P=0.05)	2.01			1.95			1.35		

Total N uptake

Phosphorus: The data reveal (Table 4.22 and Fig. 4.2) significantly higher total N uptake by chickpea with successive increase in P dose from 20 to 40 kg P_2O_5 ha^{-1} but further increase of dose from 40 to 60 kg P_2O_5 ha^{-1} remained at par with 40 kg P_2O_5 ha^{-1} over the years. On pooled basis P application up to 60 kg ha^{-1} increased total N uptake significantly. Application of 60 kg P_2O_5 ha^{-1} significantly increased total N uptake by 20.01 and 3.38 per cent, respectively over 20 and 40 kg P_2O_5 ha^{-1}.

Sulphur: Over the years the data (Table 4.22 and Fig. 4.2) show that total N uptake by chickpea crop significantly increased by increasing S level from control to 20 kg ha^{-1} but its further increase to 40 kg ha^{-1} remained at par with 20 kg S ha^{-1} during 2012-13. However, on pooled basis, increasing levels of sulphur from control to 40 kg ha^{-1} increased total N uptake by crop significantly. Pooled analysis indicates that application of 40 kg S ha^{-1} resulted in increase of 28.59 and 4.48 per cent N accumulation by crop over control and 20 kg S ha^{-1}, respectively.

Seaweed sap spray: The data (Table 4.22 and Fig. 4.2) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the total N uptake by chickpea during both the years of experimentation and on pooled basis. However, during the year 2013-14 both the seaweeds were at par during 2012-13 and on pooled basis *Kappaphycus* sap was significantly superior over *Gracilaria* sap. On pooled basis, application of *Kappaphycus* sap increased N accumulation significantly by 23.49 and 3.91 per cent, respectively over control and *Gracilaria* sap.

Interaction effect of phosphorus and sulphur: It is clear from data (Table 4.25) that interaction effect was significant with respect to total N uptake by chickpea during both the years and on pooled basis. Different levels of phosphorus in absence of sulphur significantly increased total N uptake from 20 to 60 kg P_2O_5 ha^{-1}. But when it was combined with sulphur at 20 kg ha^{-1} it significantly increased total N accumulation in chickpea up to 40 kg P_2O_5 ha^{-1}. Further increase in sulphur application to 40 kg ha^{-1} at 40 kg P_2O_5 ha^{-1} did not prove superior during both the years. On pooled basis, maximum total N uptake (79.23 kg ha^{-1}) was recorded by combined application of 60 P_2O_5 kg ha^{-1} + 20 kg S ha^{-1}, it was at par with $P_{60}S_{40}$, $P_{40}S2_0$, $P_{40}S_{40}$ and $P_{20}S_{40}$.

Table 4.25. Interaction effect of phosphorus and sulphur on total N uptake

Treatment	Total N uptake (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	45.73	65.60	79.04	45.66	67.78	78.41	45.70	66.69	78.73
P_{40}	65.04	78.36	78.63	64.24	79.42	78.08	64.64	78.89	78.35
P_{60}	72.30	80.21	76.97	72.37	78.25	78.67	72.33	79.23	77.82
S.Em.±	2.23			1.82			1.44		
CD (P=0.05)	6.69			5.46			4.15		

4.2.3.2 Phosphorus

Grain

Phosphorus: A perusal of data (Table 4.26 and Fig. 4.3) indicates that during both the years of study and on pooled basis application of 60 kg P_2O_5 ha^{-1} recorded superior to all preceding P levels in increasing P uptake by grain except during 2012-13 where it was at par with 40 kg P_2O_5 ha^{-1}. On pooled basis, application of 60 kg P_2O_5 ha^{-1} was superior by 21.12 and 5.69 per cent higher P uptake by grain over 20 and 40 P_2O_5 ha^{-1}, respectively.

Sulphur: An application of sulphur significantly increased the P uptake by grain during both the years. Pooled data showed that application of sulphur up to 40 kg S ha^{-1} increased significantly the P uptake with each level increase. Pooled analysis indicates that application of 40 kg S ha^{-1} resulted in significantly higher P uptake by grain over control and 20 kg S ha^{-1} (Table 4.26 and Fig. 4.3).

Seaweed sap spray: The data (Table 4.26 and Fig. 4.3) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the P uptake by chickpea grain but remained at par to each other during both the years of experimentation as well as on pooled basis. Compared to pooled P uptake of 4.30 kg ha^{-1} recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 25.35 and 22.09 per cent, respectively.

Interaction effect of phosphorus and sulphur: It is clear from data (Table 4.27) that interaction effect was significant with respect to P uptake by grain during both the years and on pooled basis. Significant variation was recorded due to different levels of sulphur when phosphorus was applied at 20 and 40 kg ha^{-1}. However, maximum P uptake (5.77 kg ha^{-1}) by grain was recorded by combined application of P_2O_5 at 60 kg ha^{-1} and S at 20 kg ha^{-1}, which was at par with sulphur at 40 kg with 20 kg phosphorus on pooled basis.

Table 4.27. Interaction effect of phosphorus and sulphur on P uptake by grain

Treatment	P uptake grain (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	3.60	5.02	4.94	2.78	3.83	6.55	3.19	4.42	5.74
P_{40}	4.38	4.96	6.19	4.67	5.79	4.59	4.52	5.37	5.39
P_{60}	4.86	5.66	5.88	5.13	5.89	4.90	5.00	5.77	5.39
S.Em.±	0.20			0.14			0.12		
CD (P=0.05)	0.60			0.43			0.35		

Haulm

Phosphorus: A perusal of data (Table 4.26 and Fig. 4.3) indicates that during both the years of study and on pooled basis application of 60 kg P_2O_5 ha^{-1} found superior to 20and 40 kg P_2O_5 ha^{-1} in increasing P uptake of grain. On pooled basis, application of 60 kg P_2O_5 ha^{-1} was superior by 24.81 and 6.63 per cent higher P uptake by haulm over 20 and 40 P_2O_5 ha^{-1}, respectively.

Sulphur: Application of sulphur significantly increased the P uptake by haulm during both the years. Pooled data show that application of sulphur up to 40 kg S ha^{-1} increased significantly the P uptake. Pooled analysis indicates that application of 20 and 40 kg S ha^{-1} resulted in significantly higher P uptake over control by 24.27 and 28.77 per cent, respectively (Table 4.26 and Fig. 4.3).

Seaweed sap spray: The data (Table 4.26 and Fig. 4.3) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the P uptake of chickpea haulm, but it remained at par with each other during both the years and on pooled basis. When compared with pooled P uptake of 5.20 kg ha^{-1} recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 25.19 and 21.73 per cent, respectively.

Interaction effect of phosphorus and sulphur: It is clear from data (Table 4.28) that interaction effect was significant with respect to P uptake by chickpea haulm during both the years and on pooled basis. Significant variation was recorded due to varying levels of sulphur when phosphorus applied at 20 and 40 kg ha^{-1}. On pooled basis, maximum P uptake (7.73 kg ha^{-1}) by haulm was recorded by combined application of P_2O_5 at 60 kg ha^{-1} and S at 40 kg ha^{-1}, which was significantly superior over all other treatment combinations.

Table 4.28. Interaction effect of phosphorus and sulphur on P uptake by haulm

Treatment	P uptake haulm (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	4.14	5.33	6.24	4.05	5.97	5.95	4.09	5.65	6.09
P_{40}	5.50	7.19	5.86	5.84	6.71	5.97	5.67	6.95	5.92
P_{60}	5.70	6.53	7.61	5.46	6.37	7.86	5.58	6.45	7.73
S.Em.±	0.17			0.19			0.13		
CD (P=0.05)	0.51			0.56			0.36		

Total P Uptake

Phosphorus: A perusal of data (Table 4.26 and Fig. 4.3) indicate that during both the years of study and on pooled basis application of 60 kg P_2O_5 ha^{-1} found superior to 20 and 40 kg P_2O_5 ha^{-1} in increasing total P uptake. On pooled basis application of 60 kg P_2O_5 ha^{-1} was superior by 23.02 and 6.12 per cent higher total P uptake over 20 and 40 P_2O_5 ha^{-1}, respectively.

Sulphur: Application of 40 kg S ha^{-1} significantly increased the total P uptake by chickpea crop during both the years and on pooled basis except during 2013-14 where it was at par with 20 kg S ha^{-1}. Pooled data show that application of 40 kg S ha^{-1} resulted in significantly higher total P uptake over control and 20 kg S ha^{-1} by 29.30 and 4.77 per cent, respectively (Table 4.26 and Fig. 4.3).

Seaweed sap spray: The data (Table 4.26 and Fig. 4.3) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the total P uptake by the crop. However, it remained at par to each other during both the years of study and on pooled basis. On pooled basis when compared with total P uptake of 9.50 kg ha^{-1} recorded under control, application of *Kappaphycus* sap increased it significantly by 25.26 per cent and *Gracilaria* sap by 21.89 per cent, respectively.

Interaction effect of phosphorus and sulphur: It is obvious from data (Table 4.29) that interaction effect was significant with respect to total P uptake by chickpea during second year and on pooled basis. On pooled basis, at P_{20} total P uptake was significantly increased with increase in sulphur dose up to 40 kg ha^{-1}. However, at P_{40} and P_{60}, there was significant increase the total P uptake up to S_{20}. At S_0 and S_{20} the crop responded up to P_{40}. Combined application of phosphorus at 60 kg ha^{-1} with sulphur at 40 kg ha^{-1} recorded maximum total P uptake (13.12 kg ha^{-1}), it was significantly superior over all other treatment combinations.

Table 4.29. Interaction effect of phosphorus and sulphur on total P uptake

Treatment	Total P uptake (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	7.74	10.35	11.18	6.82	9.79	12.50	7.28	10.07	11.84
P_{40}	9.88	12.15	12.06	10.52	12.50	10.56	10.20	12.32	11.31
P_{60}	10.56	12.19	13.49	10.59	12.26	12.75	10.58	12.23	13.12
S.Em.±	0.31			0.30			0.22		
CD (P=0.05)	NS			0.89			0.62		

4.2.3.3 Potassium

Grain

Phosphorus: Over the years data (Table 4.30 and Fig. 4.4) show that the progressive increase in phosphorus levels up to 60 kg P_2O_5 ha^{-1} brought about significant increase in K uptake by grain. Based on pooled analysis, the increase in K uptake due to 60 kg P_2O_5 ha^{-1} over 20 and 40 kg P_2O_5 ha^{-1} were 25.33 and 7.95 per cent, respectively.

Sulphur: The data (Table 4.30 and Fig. 4.4) reveal that K uptake by grain show statistically increasing trend by ascending S levels up to 40 kg S ha^{-1} during second year and on pooled mean but in first year it was at par with 20 kg S ha^{-1}. Pooled analysis indicate that application of 40 kg S ha^{-1} accounted for increase of 42.20 and 4.73 per cent in K uptake over no sulphur application and 20 kg S ha^{-1}, respectively. Further, pooled data show that there was significant increase in K accumulation by 20 kg S ha^{-1} application over control.

Seaweed sap spray: The data (Table 4.30 and Fig. 4.4) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the K uptake by grain during both the years of experimentation as well as on pooled basis. Pooled data further explicit that compared with K uptake of 8.08 kg ha^{-1} recorded under control, application of *Kappaphycus* sap increased it significantly by 30.45 per cent and *Gracilaria* sap by 26.49 per cent.

Interaction effect of phosphorus and sulphur: Combined application of phosphorus and sulphur significantly increase the K uptake by grain during both the years and in pooled mean. On pooled basis, different levels of phosphorus in absence of sulphur significantly increased K uptake by grain. However, when combined with sulphur at 20 kg ha^{-1}, application of phosphorus up to 40 kg P_2O_5 ha^{-1} significantly increased K accumulation in chickpea grain. Further increase in sulphur application to 40 kg ha^{-1} at same phosphorus did not prove superior. However, maximum K uptake (11.52 kg ha^{-1}) was recorded by application of P_2O_5 at 60 kg ha^{-1} with S at 40 kg ha^{-1}, which was at par with sulphur at 20 kg S ha^{-1} with phosphorus at 60 kg ha^{-1} (Table 4.31).

Table 4.31. Interaction effect of phosphorus and sulphur on K uptake by grain

Treatment	K uptake grain (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	6.39	9.02	10.51	5.62	8.79	10.34	6.01	8.90	10.43
P_{40}	7.88	10.81	10.05	8.02	10.94	11.15	7.95	10.87	10.60
P_{60}	8.63	11.21	11.80	9.25	11.41	11.23	8.94	11.31	11.52
S.Em.±	0.31			0.26			0.20		
CD (P=0.05)	0.93			0.77			0.58		

Haulm

Phosphorus: Over the years data show that the progressive increase in phosphorus levels up to 60 kg P_2O_5 ha^{-1} brought about significant increase in K uptake by haulm but it was at par with the results recorded with 40 kg. Pooled data show that increasing levels of phosphorus with each level up to 60 kg P_2O_5 ha^{-1} recorded significantly higher K uptake. Further pooled data showed that, the increase in K uptake due to 60 kg P_2O_5 ha^{-1} over 20 and 40 kg P_2O_5 ha^{-1} was 20.42 and 3.78 per cent, respectively (Table 4.30 and Fig. 4.4).

Sulphur: The data (Table 4.30 and Fig. 4.4) reveal that K uptake by chickpea haulm significantly increased by increasing S levels up to 40 kg ha^{-1} during second year and in pooled mean, but in first year it was at par with 20 kg ha^{-1}. Pooled analysis indicate that application of 40 kg S ha^{-1} accounted for an increase of 40.60 and 5.00 per cent over control and 20 kg S ha^{-1}, respectively. Application of 20 kg S ha^{-1} further showed its superiority over control (41.97 kg ha^{-1}).

Seaweed sap spray: The data (Table 4.30 and Fig. 4.4) reveal that the foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the K uptake in haulm during both the years and on pooled basis. Compared to pooled K uptake of 44.68 kg ha^{-1} recorded under control, application of *Kappaphycus* sap increased it significantly by 28.29 per cent and *Gracilaria* sap by 23.52 per cent.

Interaction effect of phosphorus and sulphur: It is clear from data (Table 4.32) that there was significant interaction between phosphorus and sulphur levels with respect to K uptake by chickpea haulm during second year and on pooled basis. On pooled basis, at P_{20} the K uptake by haulm was significantly increased due to various doses of S. However, at P_{40} and P_{60}, the K uptake by haulm was statistically higher up to S_{20} as compared to control but it was at par with S_{40}. At S_0 the crop responded up to P_{60}. At S_{20} and S_{40} the response was up to P_{40}. Combined application of phosphorus at 60 kg + sulphur at 40 kg ha^{-1} recorded maximum K uptake (61.15) it was statistically at par with $P_{60}S_{20}$, $P_{40}S_{40}$ and $P_{40}S_{20}$.

Table 4.32. Interaction effect of phosphorus and sulphur on K uptake by haulm

Treatment	K uptake haulm (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	34.43	52.87	53.92	31.35	49.96	57.78	32.89	51.41	55.85
P_{40}	43.81	58.97	60.66	43.46	58.91	59.42	43.64	58.94	60.04
P_{60}	48.62	57.99	63.03	50.17	58.48	59.27	49.40	58.23	61.15
S.Em.±	1.75			1.58			1.18		
CD (P=0.05)	NS			4.75			3.40		

Total K uptake

Phosphorus: Over the years data (Table 4.30 and Fig. 4.4) show that the progressive increase in phosphorus levels up to 40 kg P_2O_5 ha^{-1} brought about significant increase in total K uptake by chickpea haulm. However, maximum K uptake was registered with the application of 60 kg P_2O_5 ha^{-1}, but it was at par with 40 kg P_2O_5 ha^{-1}. Pooled data show that increasing levels of phosphorus with each level up to 60 kg P_2O_5 ha^{-1} recorded significantly higher K uptake. Application of 20 kg P_2O_5 ha^{-1} significantly increased total K uptake over control. The K accumulation further increased significantly by 16.02 and 21.17 per cent with application at 40 and 60 kg ha^{-1}, respectively.

Sulphur: The data (Table 4.30 and Fig. 4.4) reveal that total K uptake by chickpea showed increasing trend by ascending S levels up to 40 kg S ha^{-1} during second year and on pooled basis but in first year it was at par with 20 kg S ha^{-1}. Pooled analysis indicate that application of 40 kg S ha^{-1} accounted for an increase of 40.85 and 4.96 per cent in total K uptake by the crop over no sulphur application and 20 kg S ha^{-1}, respectively.

Seaweed sap spray: The data (Table 4.30 and Fig. 4.4) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the total K uptake during both the years of experimentation as well as on pooled basis. Pooled data further show that when compared with total K uptake of 52.75 kg ha^{-1} recorded under control, application of *Kappaphycus* sap increased it significantly by 28.64 per cent and *Gracilaria* sap by 24.00 per cent.

Interaction effect of phosphorus and sulphur: It is clear from data (Table 4.33) that interaction effect was significant with respect to total K uptake by chickpea during 2013-14 and on pooled basis. On pooled basis, at P_{20}, increasing levels of sulphur increased the total K uptake of chickpea. Similarly, there was also increase in total K uptake with the increasing levels of phosphorus at S_0. However, combined application of phosphorus at 60 kg ha^{-1} with sulphur at 40 kg ha^{-1} recorded maximum total K accumulation (72.67 kg ha^{-1}) that was at par with $P_{60}S_{20}$, $P_{40}S_{20}$ and $P_{40}S_{40}$.

Table 4.33. Interaction effect of phosphorus and sulphur on total K uptake

Treatment	Total K uptake (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	40.82	61.89	64.44	36.97	58.75	68.13	38.90	60.32	66.28
P_{40}	51.69	69.78	70.71	51.48	69.85	70.57	51.58	69.82	70.64
P_{60}	57.25	69.20	74.84	59.42	69.89	70.50	58.33	69.54	72.67
S.Em.±	1.98			1.79			1.34		
CD (P=0.05)	NS			5.36			3.85		

4.2.3.4 Sulphur

Grain

Phosphorus: The data (Table 4.34 and Fig. 4.5) reveal the increasing trend in S uptake by chickpea grain with successive increase in P dose form 20 to 60 kg P_2O_5

ha^{-1} over the years of study but 60 kg P_2O_5 recorded at par with 40 kg P_2O_5 ha^{-1}. With respect to pooled data, significant response was recorded by increasing P dose up to 60 kg ha^{-1}. Minimum S uptake (2.42 kg ha^{-1}) was recorded with 20 kg P_2O_5 ha^{-1} which significantly increased with 40 and 60 kg P_2O_5 ha^{-1} by 21.07 and 26.45 per cent, respectively.

Sulphur: A perusal of data (Table 4.34 and Fig. 4.5) indicates that during both the years and on pooled basis application of sulphur up to 40 kg ha^{-1} stood superior to all preceding S levels in increasing S uptake. On pooled basis, increase in S uptake due to 40 kg ha^{-1} over control and 20 kg S ha^{-1} was 41.15 and 7.41 per cent, respectively.

Seaweed sap spray: The data (Table 4.34 and Fig. 4.5) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the sulphur uptake during both the years of experimentation and on pooled basis. Compared to pooled sulphur uptake of 2.42 kg ha^{-1} recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 26.03 and 21.90 per cent, respectively.

Interaction effect of phosphorus and sulphur: Interaction effect between phosphorus and sulphur was significant on S uptake by chickpea grain during 2013-14 and on pooled mean basis. On pooled basis, different levels of phosphorus in absence of sulphur significantly increased S uptake by grain from 20 to 60 kg P_2O_5 ha^{-1}. But when combined with sulphur at 20 and 40 kg ha^{-1} it significantly increased S accumulation in chickpea grain up to 40 kg P_2O_5 ha^{-1}. Further increase in phosphorus dose to 60 kg ha^{-1} did not prove superior. However, maximum K uptake (3.40 kg ha^{-1}) was recorded by combined application of P_2O_5 at 60 kg ha^{-1} + S at 40 kg ha^{-1}, which was at par with $P_{60}S_{20}$ and $P_{40}S_{40}$ (Table 4.35).

Table 4.35. Interaction effect of phosphorus and sulphur on S uptake by grain

Treatment	S uptake grain (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	1.75	2.49	2.90	1.88	2.53	2.99	1.82	2.51	2.94
P_{40}	2.34	3.19	3.14	2.43	3.21	3.31	2.38	3.20	3.22
P_{60}	2.46	3.17	3.46	2.70	3.24	3.33	2.58	3.21	3.40
S.Em.±	0.10			0.08			0.07		
CD (P=0.05)	NS			0.24			0.19		

Haulm

Phosphorus: The data (Table 4.34 and Fig. 4.5) reveal significantly higher S uptake by haulm with successive increase in P dose form 20 to 40 kg P_2O_5 ha^{-1} over the years of study. Further increase in P dose to 60 kg P_2O_5 ha^{-1}, chickpea haulm failed to accumulate significantly higher S over 40 kg P_2O_5 ha^{-1}. On pooled basis, significant response was recorded by increasing P dose up to 60 kg ha^{-1}. Significantly higher 22.73 and 4.35 per cent S uptake due to application of 60 kg P_2O_5 ha^{-1} was recorded over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: A perusal of data (Table 4.34 and Fig. 4.5) indicates that during both the years and on pooled basis application of sulphur up to 40 kg ha^{-1} found superior to control and 20 kg S ha^{-1} in increasing S uptake in chickpea haulm. On pooled basis, the increase in S uptake due to 40 kg S ha^{-1} over control and 20 kg S ha^{-1} was 37.80 and 8.65 per cent, respectively.

Seaweed sap spray: The data (Table 4.34 and Fig. 4.5) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the S uptake in haulm during both the years of experimentation and on pooled basis. On pooled basis, when compared with S uptake of 1.73 kg ha^{-1} recorded under control, application of *Kappaphycus* sap increased it significantly by 25.43 per cent and *Gracilaria* sap by 20.81 per cent.

Interaction effect of phosphorus and sulphur: It is clear from data (Table 4.36) that there was significant interaction between levels of phosphorus and sulphur in respect to S uptake by chickpea haulm during both the year and on pooled basis. On pooled basis, significant increase was recorded due to different levels of sulphur when phosphorus applied at 20 and 40 kg ha^{-1}. Further increase in level of phosphorus to 60 kg ha^{-1}, there was non-significant response to sulphur levels. Maximum S uptake by chickpea haulm was recorded by combined application of phosphorus at 60 kg and sulphur at 40 kg ha^{-1}, and it was statistically at par with $P_{40}S_{40}$.

Table 4.36. Interaction effect of phosphorus and sulphur on S uptake by haulm

Treatment	S uptake haulm (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	1.30	1.79	2.08	1.40	1.88	2.09	1.35	1.83	2.08
P_{40}	1.67	2.23	2.38	1.70	2.22	2.23	1.68	2.23	2.31
P_{60}	1.92	2.32	2.33	1.88	2.07	2.45	1.90	2.19	2.39
S.Em.±	0.06			0.06			0.04		
CD (P=0.05)	0.17			0.19			0.12		

Total S uptake

Phosphorus: The data (Table 4.34 and Fig. 4.5) reveal that total S uptake was higher successively with increase in P dose form 20 to 60 kg P_2O_5 ha^{-1} over the years of study as well as on pooled basis. However, during both the year significant response was recorded with increasing P dose up to 40 kg ha^{-1}. On pooled basis significantly higher total S accumulation was found with successive increase in P dose from 20 to 60 kg P_2O_5 ha^{-1}. Maximum total S uptake was recorded in chickpea plant at 60 kg P_2O_5 ha^{-1}, it was 24.88 and 4.19 per cent higher over 20 and 40 kg P_2O_5 ha^{-1}, respectively.

Sulphur: A perusal of data (Table 4.34 and Fig. 4.5) indicates that in both the years and on pooled basis application of sulphur up to 40 kg ha^{-1} found superior to control and 20 kg S ha^{-1}. On pooled basis, the increase in S uptake as a result of 40 kg S ha^{-1} over control and 20 kg S ha^{-1} was 39.74 and 7.92 per cent higher, respectively.

Seaweed sap spray: The data (Table 4.34 and Fig. 4.5) reveal that foliar application of *Kappaphycus* and *Gracilaria* saps significantly increased the total S uptake in chickpea during both the years and on pooled basis. However, both the seaweed saps were found equally effective in total S accumulation in chickpea in both the years. On pooled basis when compared with S uptake of 4.15 kg ha^{-1} recorded under control, application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 25.54 and 21.45 per cent, respectively.

Interaction effect of phosphorus and sulphur: It is clear from the data (Table 4.37) that there was significant interaction between levels of phosphorus and sulphur in respect to total S uptake by chickpea on pooled basis. However, during both the years of investigation the interaction effect was non-significant on total S uptake by chickpea. On pooled basis, significant variation was recorded in levels of sulphur when phosphorus was applied at 20 and 40 kg ha^{-1}. With further increase in the level of phosphorus to 60 kg ha^{-1}, there was non-significant response to sulphur levels. Maximum total S uptake by chickpea was recorded by combined application of phosphorus at 60 kg and sulphur at 40 kg ha^{-1}, which was at par with that of $P_{40}S_{40}$.

Table 4.37. Interaction effect of phosphorus and sulphur on total S uptake

Treatment	Total S uptake (kg ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	3.05	4.28	4.98	3.28	4.40	5.08	3.17	4.34	5.03
P_{40}	4.01	5.42	5.51	4.12	5.43	5.54	4.07	5.42	5.53
P_{60}	4.37	5.48	5.79	4.58	5.32	5.79	4.48	5.40	5.79
S.Em.±	0.15			0.13			0.10		
CD (P=0.05)	NS			NS			0.29		

4.3 SOIL ANALYSIS AFTER HARVEST OF CROP

4.3.1 Available Nitrogen

Phosphorus: An appraisal of the data (Table 4.38) reveal that the status of available nitrogen in chickpea after harvest of the crop was significantly higher by raising phosphorus levels up to 40 kg P_2O_5 ha^{-1}, but its further increase to 60 kg did not increase it significantly during both the years as well as on pooled basis. On pooled average basis, increase in status of available N in soil after the application of 40 and 60 kg P_2O_5 ha^{-1} was of the order of 5.49 and 8.10 per cent over 20 kg ha^{-1}, respectively.

Sulphur: It was found that the status of available N in the soil was not affected significantly by sulphur fertilization (Table 4.38).

Seaweed sap spray: An appraisal of data (Table 4.38) reflects that status of available nitrogen in soil was not affected significantly by different seaweed sap sprays.

4.3.2 Available Phosphorus

Phosphorus: A perusal of data in Table 4.38 indicates that successive increase in phosphorus levels from 20 to 60 kg P_2O_5 ha^{-1} tended to significantly increase in the status of available P in the soil after harvest of chickpea in both the years and on pooled basis. Analysis of pooled data indicates that raising of phosphorus dose from 20-40 and 40-60 kg P_2O_5 ha^{-1} was associated with 14.97 and 10.75 per cent increase in the status of phosphorus in the soil after harvest of chickpea, respectively.

Sulphur: An appraisal of data (Table 4.38) also reflects that the available phosphorus in the soil was not affected significantly by sulphur fertilization.

Seaweed sap spray: It was found that status of available P in the soil was not affected significantly by different foliar sprays (Table 4.38).

4.3.3 Available Potassium

Available potassium content in chickpea after harvest of crop remained statistically unaffected by phosphorus, sulphur and seaweed saps application (Table 4.38).

4.3.4 Available Sulphur

Phosphorus: It was also found that available sulphur status of the soil was not affected significantly by phosphorus fertilization (Table 4.38).

Sulphur: An examination of data presented in Table 4.38 indicates that application of 40 kg S ha^{-1} was statistically superior as compared to control and 20 kg S ha^{-1} in enhancing available sulphur content in the soil after crop harvest during both the years and on pooled basis. Pooled data reveal 33.48 and 10.29 per cent higher build up of available sulphur in soil after harvest of the crop over control and 20 kg S ha^{-1} through application of 40 kg S ha^{-1}, respectively.

Seaweed sap spray: It was found that the status of available sulphur in the soil was not affected significantly by foliar sprays of different seaweed saps (Table 4.38).

4.4 ECONOMICS

4.4.1 Net returns

Phosphorus: The data (Table 4.39 and Fig. 4.6) reveal that in both the years of study and on pooled basis, significantly greater net returns was obtained with the application of 60 kg P_2O_5 ha^{-1} which was at par with 40 kg P_2O_5 ha^{-1}. On pooled basis 40 and 60 kg P_2O_5 ha^{-1} registered 16.04 and 18.62 per cent higher net returns over 20 kg P_2O_5 ha^{-1}, respectively.

Sulphur: The figures are clear in presenting the significance of 40 kg S ha^{-1} over control and 20 kg S ha^{-1} on pooled basis but at par with 20 kg in both the years. Pooled statistics (Table 4.39 and Fig. 4.6) indicate that application of 20 and 40 kg S ha^{-1} resulted in 35.92 and 43.51 per cent increase in net returns over control, respectively.

Seaweed sap spray: The data (Table 4.39 and Fig. 4.6) indicate the significance of the foliar application of *Kappaphycus* and *Gracilaria* saps over control in making more net returns from cultivation of chickpea during both the years of experimentation and on pooled basis. On the basis of pooled data when compared with net returns of ₹ 26620 ha^{-1} recorded under control, foliar application of *Kappaphycus* and *Gracilaria* saps increased it significantly by 17.75 and 13.22 per cent, respectively over control.

Interaction effect of phosphorus and sulphur: The interaction effect was significant between phosphorus and sulphur at changing levels with regard to net returns during both the years and on pooled basis. On pooled basis, at each level of phosphorus, application of sulphur showed variable response. Also variability in significance of phosphorus under different S levels was evident. Under no sulphur application, response of phosphorus was significant up to 60 kg ha^{-1} of P_2O_5. Similarly combined application of phosphorus at 20 kg P_2O_5 ha^{-1} with graded levels of sulphur up to 40 kg P_2O_5 significantly increased net returns of chickpea. While, the response was significant up to 40 kg P_2O_5 ha^{-1}, when sulphur was applied at 20 kg ha^{-1}. The highest net returns (₹ 33929) was registered by conjoint application of 20 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1} which was at par with phosphorus at 40 with sulphur at 40 kg ha^{-1}, phosphorus at 40 kg with sulphur at 20 kg ha^{-1}, phosphorus at 60 kg with Sulphur at 20 and 40 kg ha^{-1}. (Table 4.40).

Table 4.40. Interaction effect of phosphorus and sulphur on net returns

Treatment	Net returns (₹ ha^{-1})								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	17156	27748	33062	15989	29209	34796	16573	28479	33929
P_{40}	23938	32611	32365	25952	34319	34117	24945	33465	33241
P_{60}	27377	31728	31783	28910	33749	33824	28144	32738	32804
S.Em.±	1532			1543			1087		
CD (P=0.05)	4594			4626			3132		

4.4.2 B C ratio

Phosphorus: Application of phosphorus at 40 kg P_2O_5 ha^{-1} resulted in significantly higher B C ratio during 2013-14 and on pooled basis over 20 kg P_2O_5 ha^{-1} while, B C ratio were non-significant during 2012-13. However, further increase in phosphorus dose to 60 kg ha^{-1} found non-significant with 40 kg (Table 4.39). On pooled basis, application of 40 kg P_2O_5 ha^{-1} registered significantly higher B C ratio over 20 kg P_2O_5 ha^{-1} which was statistically at par with higher dose of 60 kg P_2O_5 ha^{-1}. The increase in B C ratio with 40 kg P_2O_5 over 20 kg P_2O_5 was 11.38 per cent.

Sulphur: It was found that increase in S levels from control to 40 kg ha^{-1} progressively increased B C ratio during both the years and on pooled basis. However, it was at par with 20 kg S ha^{-1}. Pooled analysis reveal that 40 kg S ha^{-1} gave 1.49 of B C ratio which was significantly higher by 4.93 and 43.27 per cent over 20 kg S ha^{-1} and control, respectively (Table 4.39).

Seaweed sap spray: B C ratio of chickpea crop remained unaffected statistically by seaweed sap application (Table 4.39).

Interaction effect of phosphorus and sulphur: A perusal of data (Table 4.41) showed that the interaction between phosphorus and sulphur was significant on B C ratio of chickpea crop during both the years and on pooled basis. During 2012-13 at P_{20} there was significant increase in B C ratio with sulphur up to 40 kg ha^{-1}. However at P_{40} and P_{60}, the B C ratio was statistically higher at S_{40} as compared to control but it was at par with S_{20}. At S_0 and S_{20} the crop responded up to P_{40}. During 2013-14 at P_{20} there was significant increase in B C ratio up to S_{40}. On pooled basis, at P_{20} there was significant increase in B C ration with increasing levels of sulphur up to 40 kg S ha^{-1}. At P_{40} and P_{60} the significant response was recorded up to 20 S. At S0 and S20 the significant response was recorded up to phosphorus at 40 kg ha^{-1}. Further increase in dose of sulphur there was no significant response recorded. Combined application of phosphorus at 20 kg ha^{-1} with sulphur at 40 kg ha^{-1} recorded highest B C ratio (1.58) it was at par with $P_{40}S_{20}$ and $P_{40}S_{40}$.

Table 4.41. Interaction effect of phosphorus and sulphur on B C ratio

Treatment	B C ratio								
	2012-13			2013-14			Pooled		
	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}	S_0	S_{20}	S_{40}
P_{20}	0.83	1.33	1.56	0.73	1.35	1.59	0.78	1.34	1.58
P_{40}	1.09	1.51	1.47	1.15	1.53	1.50	1.12	1.52	1.48
P_{60}	1.20	1.39	1.38	1.23	1.43	1.43	1.21	1.41	1.41
S.Em.±	0.07			0.07			0.05		
CD (P=0.05)	0.21			0.21			0.14		