1. INTRODUCTION

Pulses form an important segment of Indian agriculture after cereals and oilseeds. About 76 per cent of the global pigeonpea, 70 per cent of chickpea and 39 per cent of lentil area falls in India (FAO, 2011). India is the largest producer and consumer of pulses in the world, contributing to around 25-26 per cent to global basket of 67.71 million tonnes (Ali *et al.*, 2012). The country grows a variety of pulse crops under wide range of agro-climate conditions. The estimates for 2012-13 indicate that the total pulse production was 18.45 million tonnes from 23.47 million ha area, majority of which fall under rainfed, resource poor and harsh environments frequently prone to drought and other abiotic stress conditions (Directorate of Economics and Statistics, 2013). Pulses are least preferred by farmers because of high risk and less remunerative than cereals; consequently, the production of the pulses is low. India at present is importing about 3 million tonnes of pulses from other countries to fulfill the domestic needs. By the year 2030, country's population is predicted to touch 1.68 billion mark from the present level of 1.21 billion. Accordingly, the projected pulse requirement for the year 2030 would be 32.00 million tonnes with an anticipated growth rate of 4.2 per cent (IIPR, 2011). The per capita availability of pulses has come down from 60 g capita^{-1} day^{-1} in 1951 to 39.4 g capita^{-1} day^{-1} in 2011 due to increasing population and stagnant production, while, ICMR recommends the use of pulses at the rate of 65 g capita^{-1} day^{-1} to fulfill the nutritional requirements of an individual (Government of India, 2012-13). In view of this, we have to develop and adopt progressively more productive and efficient technologies to encourage farmers to bring more area under pulses.

Chickpea is the third important pulse crop in the world after frenchbean and field pea, with an acreage of 13.54 million ha, production of 13.10 million tonnes and productivity of 967 kg ha^{-1} (FAO, 2015). It is also the premier food legume crop of India, which is grown on about 8.70 million ha area producing 8.83 million tones, representing 37.06 per cent and 47.86 per cent of the national pulses area and production, respectively. Rajasthan is the second largest gram producing state which shares nearly 14.37 per cent of acreage and 14.30 per cent of total gram production of our country. In Rajasthan, gram enjoys a respectable position, but the performance is rather gloomy. In 2012-13 gram was cultivated over an area of 1.25 million ha which provided total production of 1.27 million tonnes. The productivity of state was 1016 kg ha^{-1} as against average national productivity of 1021 kg ha^{-1} (Directorate of Economics and Statistics, 2013).

A number of factors, including genetic and environmental are responsible for low yield of pulses. Among agronomic factors, imbalance fertilization is the key factor responsible for low yields. Phosphorus is one of the nutrients required in large quantity for optimum growth and yield of pulses. Chickpea is generally considered to be highly efficient in extracting phosphorus from low phosphorus soils due to the production of acidic root exudates which dissolve insoluble soil P. Phosphorus is the element for which prudent management is required. An adequate supply of phosphorus has been reported by various workers to be beneficial for vigorous growth, bumper yield, better quality and enormous nodule formation in legume crops. It participates in metabolic activities as a constituent of nucleoprotein and nucleotides and also plays a key role in the formation of energy rich phosphate bond like Adenosine-di-phosphate and Adenosine-tri-phosphate. The response of phosphorus varies from location to location. However, in areas where legumes are traditionally grown without phosphorus, poor nodulation was observed with low yield. The efficiency of legume as soil renovator increases with the application of phosphorus. The added phosphorus is reported to serve dual purpose of increasing the yield of legume and other crops as well as that of succeeding crop.

In addition to phosphorus, sulphur is also one of the important plant nutrients and has been reported to be deficient in soils of Jaipur, Jodhpur and Udaipur districts of Rajasthan (Tandon, 1986). Due to continuous use of high analysis fertilizers like urea and DAP and high yielding varieties, sulphur deficiency has been reported in many crops, specially oilseeds and pulses. Sulphur is constituent of three amino acids *viz*., methionine, cysteine and cystine, deficiency of which results in serious malnutrition. The vitamins biotin and thiamine contain sulphur and the structure of protein is determined to a considerable extent by sulphur groups. Sulphur also improves nodulation in legumes (Shivran and Prakash, 2012). The properties of certain proteins and enzymes which are concerned with photosynthesis and nitrogen fixation are thought to be property of the type of sulphur linkage present. Elemental sulphur has been found to be an effective source but it is costly and involves foreign exchange whereas, gypsum appears to be the cheap and easily available sulphur carrier in Rajasthan.

Disadvantages of chemical fertilizers have led farmers turning toward suitable organic source of plant nutrients. To meet increasing demand of organic sources, among many viable options, one is use of seaweed extracts (SEs). In recent years, the use of natural seaweed products as substitute to conventional chemical fertilizers has assumed importance (Lingakumar *et al.*, 2002). Application of seaweed preparation as a substitute of fertilizer has many beneficial effects on plants (Norrie and Hiltz, 1999). Many claims have been made for seaweed extract including increased frost resistance, increasing nutrient uptake and change in plant tissue composition, increased resistance to fungal diseases, reduced incidence of insect attack, higher yields, longer shelf-life of produce, improved animal health when livestock are grazed on treated pastures, deeper root developments and better seed germination (Zodape, 2001), delay of fruit senescence, improved plant vigour, yield, quality and also improved ability to withstand adverse environmental conditions (Selvaraj *et al.*, 2004). Seaweed extracts are commonly applied to crops as root dips, soil drenches or foliar sprays. These extracts contain major and minor nutrients, amino acids, vitamins, and also cytokinins, auxins, and ABA like growth substances. Positive responses observed in different crops with the application of SEs are attributed to the presence of cytokinin (Crouch and Van Staden 1993). Seaweed extract was found to be superior to chemical fertilizer because of high level of organic matter which aids in retaining moisture and minerals in upper soil level available to roots (Sivasankari *et al.*, 2006). Significant increase in yield of different crops due to foliar application of SEs has been reported (Arthur *et al.*, 2003 and Zodape *et al.*, 2008). *Kappaphycus alvarezii* and *Gracilaria* sp. extracts were found to be rich in nutrients as well plant growth promoting substances like IAA, kinetin, zeatin and gibberellins.

Most soils of Rajasthan state are deficient in organic matter content and poor in nutrient supply, hence, introduction of suitable seaweed sap may help in boosting up production because of increased organic matter, which is rich in nutrients including plant growth promoting substances. In addition, widespread deficiency of sulphur in Indian soils warrants its addition to the fertilization programmes. The nutrient needs of pulses especially for sulphur and phosphorus are more important and their suitable combination to keep pace with nutrient required by crop and to get potential production cannot be met either through mineral fertilizers or through organics alone. The efficient and judicious use of all the sources of nutrients in an integrated manner would be essential and inevitable to increase the production of pulses in the country. Therefore, it is time to develop a strategy for suitable combination of phosphorus, sulphur and organic supplements to boost the chickpea production. Keeping the above facts in view, it was considered appropriate to carry out an investigation entitled "**Effect of Phosphorus, Sulphur and Seaweed Sap on Productivity of Chickpea (*Cicer arietinum* L.)''** with the following objectives:

(i) To standardize phosphorus and sulphur levels for chickpea,

(ii) To assess the effects of seaweed saps spray on growth, productivity and quality of chickpea,

(iii) To study the effect of phosphorus, sulphur and seaweed sap on dry matter partitioning of chickpea, and

(iv) To arrive at economically viable recommendation of treatments.