



# Influence of Vermicompost and Sulphur on Groundnut (*Arachis hypogaea*) - Wheat (*Triticum aestivum*) Cropping Sequence under Loamy Sand Soil

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

A field experiment was conducted at RARI, Durgapura-Jaipur in irrigated coarse textured agro ecological situations during Rabi 2014-15, 2015-16 & 2016-17 to find out the effect of sulphur and vermicompost application on grain and straw yield of wheat under groundnut – wheat crop

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sequence. Twelve treatments were taken in randomized block design with three replications, variety Raj- 3765 of wheat was taken as test crop. Three, years pooled data revealed that significantly higher grain and straw yield was obtained where, vermicompost was applied @ 6t/ha which is at par with T<sub>5</sub> where V. C. was applied @ 2t/ha. Soil application of V. C. @ 6t/ha + S @ 45kg /ha+ N P K gave significantly highest grain and straw yield (50.75 & 72.44 q/ha) of wheat over treatment T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>7</sub> and T<sub>10</sub> and at par with T<sub>5</sub> and rest of the treatment. The lowest yield was recorded in T<sub>1</sub> (37.05& 52.15 q/ha). Three-year pooled data of ground nut revealed that soil application of vermicompost @ 6t/ha + S @ 45kg /ha+ N P K gave significantly highest pod yield (43.15 q/ha) of groundnut over treatment T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>7</sub> and T<sub>10</sub> and at par with T<sub>6</sub> where vermicompost was applied @ 2 t/ha and sulphur was applied @ 45kg/ha (40.08 q/ha) and rest of the treatments. The lowest yield was recorded in T<sub>1</sub> (30.51 q/ha).

**Keywords:** Sulphur; vermicompost; cropping sequence; system wheat equivalent yield.

## 1. INTRODUCTION

“Improving and maintaining soil quality for enhancing and sustaining agricultural production is of almost importance for world’s food and nutritional security. Natural resources viz. land and water available for agricultural production is limited in most of the regions in world. So increasing yields from current limited available land is the only solution in order to feed the increasing population (Bouyoucos, 1962). Integrated plant nutrition supply system is the only possible way, which can reduce the dependency on chemical fertilizer (CF) to attain the sustainable and profitable production without causing detrimental effect on soil and environment. The increasing cost of CF day by day is a serious matter of concern and their frequent application is deteriorating bio-physico chemical properties of soil” (Mahajan *et al.* 2008; Bremner & Nelson, 1982). “This in turn is leading to reduction in crop yield per unit area. Besides fertilizers there are several sources of plant nutrients like organic manures and biofertilizers” (Sreedevi *et al.* 2013). Moreover, “it will enhance soil health which is the balance between soil function for productivity, environmental quality, and plant and animal health” (Doran and Zeiss 2000, Doran 2002). “Application of organic manures helps in mitigating multiple nutrient deficiencies at the same time previous better environment for growth and development by improving in physical, chemical and biological properties of soil” (Avitoli *et al.* 2012; Heywood, 1971). “Vermicompost has been recognized as a low cost and environmentally sound process for treatment of many organic wastes” (Hoitink, 1993). Furthermore, “the rapid decomposition and raised temperatures during composting produces a relatively homogeneous, odor-free, pathogen- free and easy to handle product” (Bevacqua and Mellano 1993) reported that vermicompost treated soil and lower pH and

increased levels of organic matter primary nutrients and soluble salt (Edwards and Burrows 1988). “Vermicompost contain plant nutrients including N, P, K, Ca, Mn, Zn and Cu the uptake of which has a positive effect on plant nutrients, photosynthesis and improves the nutrient content of the different plant components (GOR, 2018). The soil properties such as pH, EC, available nitrogen, phosphorous, and potassium were found to vary in the soil treated with vermicompost application” (Mathivanan *et al.* 2013). “Sulphur involved in chlorophyll formation, activation of enzymes and is a part of vitamins such as biotin and thiamine (B1)” (Hedge and Sudha Karanbabu 2007). It is master nutrient for oil seed production as each unit of fertilizers S generates 3-5 units of edible oil (Ramdevputra *et al.* 2010). “Role of S in Indian agriculture is now gaining importance because of the recognition of its role in increasing crop production, not only of oilseed, pulses, legumes and forage but also of many cereals” (Singh *et al.* 2000). “Sulphur deficiency is extensive particularly in the areas where crop is intensively cultivated with the use of S free fertilizers” (Basak *et al.* 2000; Hegde & Sudhakarababu, 2007). At present deficiency in soils various Indian states varies from 5-83 % with an overall mean of 41% (Singh 2001). “Sulphur is essential for growth and development of groundnut deficiencies of S is widespread in soils of India and is becoming a major concern for the quality and yield of ground crop” (Kumar *et al.* 2019). “Nutrient requirement varies with different crop in the system and if investigated systematically, may help to regulate the nutrient demands of the succeeding crops in terms of saving in fertilizers and changes in soil fertility use of chemical fertilizers has deleterious effect on soil which in turn cause decline in productivity, low nutrient recovery efficiency and increased in cost of production and environmental pollution” (Sarkar *et al.* 1997; Kumar *et al.*, 2008). Application of organic manure may also improve

availability of native nutrients in soil as well as the efficiency of applied fertilizers (Sawrup 2010). Solanki 2020 reported that application of sulphur along with different doses of FYM or vermicompost improve the soil health and increased availability of nutrient in soil.

“Groundnut is annually grown on about 24 M ha of land in about 120 countries under different agro climatic zone between 40 S and 40 N (DGR). It occupies premier position with regard to area and production in India account about 20 percent areas and less than 10 percent production of oilseed of the world. Whereas groundnut account for 40 percent of the area and 30 percent of the production of total oilseeds grown in the country (Anonymous 2009-10). In India, it was cultivated on an area of 5.53 m ha with production of 9.67 MT and productivity of 1750 kg/ha during 2013-14” (AICRPG. 2015). “Currently six states viz. Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra and Rajasthan account for more than 90 % of the total groundnut area and 89.3 % of total production. Groundnut is the principle kharif oilseed crop of the state Rajasthan. It was grown on 3.97 lakh hectares in the state with total production of 4.18 lakh tones and average production of 1051 kg/ha” (Anonymous 2012; Tathe, 2008). “In Rajasthan it is mainly grown in arid and semi-arid district of Ganganagar, Hanumangarh, Jaipur, Bikaner, Sikar, Churu, Jodhpur, Chittorgarh and Nagaur. Despite of being such an important oilseed crop the average productivity in the state is lower than Nation level as well as its production potential. Sulphur is now recognized as the fourth major plant nutrient after N, P and K and also an integral part of balanced fertilization and nutrition for oilseed crops in general and groundnut in particular. In Rajasthan it has been reported to be deficient mainly in the soil of Jaipur, Jodhpur and Udaipur district” (Tandon, 1986). Global reports of sulphur deficiency and consequent crop responses, particularly oilseed crops like groundnut are quite ostensible (Singh and Bairathi 1980). Shah and Khan also observed that oilseed crops respond remarkably to sulphur and balanced fertilization. (Giri et al. 2011), (Desh et al. 2013), (Rao et al. 2013), and (Kulkarni et al. 2018) also observed the positive response of sulphur application they reported that yield and yield attributes also exhibited similar trend with a significantly increased response due to organic and inorganic treatments in groundnut and wheat respectively. The benefits of the legumes in cereals cropping

system are well established. Legumes are reported to have favorable important on the soil fertility and help in increasing the yield of succeeding crop (Jain et al. 2005; Rodriguez et al., 2012). Legumes have the ability to fix atmospheric nitrogen and converted it to a useable form for plant growth (Allen and Allen 1981). Wheat (*Triticum aestivum*) is the most important cereal crop for majority of the world's population (Yadav et al., 2019). It is cultivated under diverse growing conditions of soil and climate. In India, it is the second most important food crop after rice. Wheat was grown on an area of 29.6 million ha with production of 99.7 MT and productivity of 3371 kg/ha (GOI, 2018). Groundnut-wheat is an important cropping system of agro climatic zone IIIA of Rajasthan with groundnut as a kharif and wheat as a rabi season crop particularly under irrigated condition. Hence, the present investigation was carried out to study the effect of vermicompost and sulphur (through gypsum) on nutrient status, uptake, yield and economics of groundnut-wheat cropping sequence as influenced by vermicompost and sulphur under loamy sand soil.

## 2. MATERIALS AND METHODS

**Raw Materials:** Gypsum was procured from G S S Bilwa Jaipur. The powder form of gypsum (100-mesh) was used for study. The technical values of gypsum composition are  $\text{CaSO}_4 \cdot \text{H}_2\text{O}$ . Crop residues and cow dung was obtained from the research farm of Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur.

**Location of the experimental area and climate:** The Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur is situated at 26° 51 N latitude and 75° 47 E longitude at an elevation of 390 M above sea level. The climate of RARI zone with hot and dry summer (May-June) and cold winter (December – January, intervened by short monsoon period 2 to 3 months mainly spread during July to September on the basis of 10 year of climatic data, the mean maximum temperature, minimum temperature and rainfall were 31.90°C, 18.90°C and 550 mm, respectively. On an average 90% of the mean annual rainfall is received from July to September and 10 % during winter months i.e. November to March.

**Soil:** The experimental area represented semi-arid eastern plan zone of Rajasthan and taxonomically is belonging to mixed hyper thermic typic Ustipsament. The experimental soil

**List 1. Methods used for soil analysis**

S. No	Test parameter	Methods	References
1	Organic Carbon	Oxidation method	Walkley and Black (1934)
2	Total N in plant	Micro-kjendahl method	Parkinson and Allen 1975
3	Total P in plant	Vanadomolybdate method	Jackson 1973
4	Total K in plant	Flame photometer method	Chapman and Pratt 1961
5	Total S in plant	Turbiditic method	Chesin and Yien 1951
6	Available N	Micro-kjendahl method	Keeney and Nelson, 1982
7	Available P	Spectrophotometer method	Olsen <i>et al.</i> 1954
8	Available K	Flame photometer Method	Hanway and Heidel, 1952
9	Available S	Turbiditic method	Chesin and Yien 1951
10	pH	Glass Electrode	Jackson 1973
11	EC	Conductivity Bridge	Jackson 1973

is alluvial, loamy sand in texture with low CEC, alkaline in reaction free from salinity and has nearly level to gently sloping topography. Clay mineralogy is dominated by mica along with presence of kaolinite, vermiculite, chlorite mica and smectite mica.

**Layout of the experiment:** A field experimental during monsoon (kharif) season of 2014 to 2016 and winter (rabi) season of 2015 to 2017 was conducted on groundnut and wheat at experimental research farm RARI, Durgapura, Jaipur, India. Following twelve treatments were used for conducting the present field experiment.

- T<sub>1</sub>: Recommended dose of fertilizer (RDF) NPK + vermicompost 2t ha<sup>-1</sup>  
 T<sub>2</sub>: RDF NPK + vermicompost 4t ha<sup>-1</sup>  
 T<sub>3</sub>: RDF NPK + vermicompost 6t ha<sup>-1</sup>  
 T<sub>4</sub>: RDF NPK + vermicompost 2t ha<sup>-1</sup> + Sulphur 15 kg ha<sup>-1</sup>  
 T<sub>5</sub>: RDF NPK + vermicompost 2t ha<sup>-1</sup> + Sulphur 30 kg ha<sup>-1</sup>  
 T<sub>6</sub>: RDF NPK + vermicompost 2t ha<sup>-1</sup> + Sulphur 45 kg ha<sup>-1</sup>  
 T<sub>7</sub>: RDF NPK + vermicompost 4t ha<sup>-1</sup> + Sulphur 15 kg ha<sup>-1</sup>  
 T<sub>8</sub>: RDF NPK + vermicompost 4t ha<sup>-1</sup> + Sulphur 30 kg ha<sup>-1</sup>  
 T<sub>9</sub>: RDF NPK + vermicompost 4t ha<sup>-1</sup> + Sulphur 45 kg ha<sup>-1</sup>  
 T<sub>10</sub>: RDF NPK + vermicompost 6t ha<sup>-1</sup> + Sulphur 15 kg ha<sup>-1</sup>  
 T<sub>11</sub>: RDF NPK + vermicompost 6t ha<sup>-1</sup> + Sulphur 30 kg ha<sup>-1</sup>  
 T<sub>12</sub>: RDF NPK + vermicompost 6t ha<sup>-1</sup> + Sulphur 45 kg ha<sup>-1</sup>

The field experiment was laid out in randomized block design with three replication wheat was sown in rows 22.5 cm apart and for groundnut geometry of 30 cm X 10 cm was maintained. The

full quantity of vermicompost and sulphur (through gypsum) was applied only to groundnut crop at the time of field preparation for sowing. Vermicompost and sulphur was applied only in groundnut and its residual effect was evaluated in subsequent wheat crop. In groundnut recommended dose of fertilizer N, P, and K (20, 60, 30 kg/ha) was applied at the time of sowing. In wheat full quantity of phosphorous and potash (40 and 30 kg/ha) was applied at the time of sowing and nitrogen was applied (120 kg/ha) in two split doses half quantity of nitrogen was applied at the time of sowing and remaining was top dressed at the time of first irrigation (21 days after sowing) before the groundnut sowing the plot were ploughed three times with the help of a tractor drawn cultivator to a depth of 15 cm then individual beds were made. The whole quantity of vermicompost and sulphur (gypsum) and inorganic fertilizer were applied before last ploughing and incorporated into soil.

### 3. RESULTS AND DISCUSSION

#### Yield and Yield Attributes of Groundnut:

**Pod, Haulm and Kernal yield:** In the present experiment different treatments combination of vermicompost and sulphur had significant effect on pod, haulm and kernel yield. The three yeas pooled data presented in Table 3 and Fig. 1 revealed that among the various tested combination, highest pod, haulm and kernel yield (43.14, 60.75 and 30.88 q/ha) was observed in treatment T<sub>12</sub> where, vermicompost was applied 6 t/ha and sulphur was applied 45 kg/ha. Soil application of V.C. 6 t/ha + sulphur 45kg/ha along with recommended dose of NPK (T<sub>12</sub>) gave significantly highest pod, haulm and kernel yield over treatment T<sub>1</sub>, T<sub>2</sub> T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>7</sub> and T<sub>10</sub>. However, it was at par with T<sub>6</sub> (RDF NPK+ V.C. 4t/ha+ S 45kg/ha) and rest of the treatment. The

lowest yield of dry pod, haulm and kernel was recorded in T<sub>1</sub> (RDF NPK+ V.C. 2t/ha) 3.52, 43.60 and 20.89 q/ha of dry pod, haulm and kernel respectively. Application of S increased the dry matter yield (DMY) of haulm, pod and kernel of groundnut. The analysis of variance showed that yield of groundnut was significantly influenced by the application of different doses of S. likewise graded increasing in levels of sulphur from 15 to 45 kg/ha gave significantly higher pod, and kernel yield as compared with each other but in haulm it was at par with increasing levels of sulphur from 30 to 45 kg/ha. Increasing levels of vermicompost from 2 to 6 t/ha gave significantly higher pod, haulm and kernel yield as compared with each other. Vermicompost showed better results in respect to yield because of higher exchangeable k, ca and mg content in vermicompost compared to conventional compost, which increased crop yield (Sunhane *et al* 2008). The lowest values of pooled dry pod, haulm and kernel yield of groundnut were registered in T<sub>1</sub> (RDF NPK + VC 2t/ha) this might be due to less availability of nutrients from soil. Higher yield of haulm, dry pod and kernel was recorded with application of S 45 kg/ha than that with lower S status, such lower response with application of 15 to 30 kg ha<sup>-1</sup> S may be due to deficiency of S in soil. Response of groundnut to applied S had also been reported by (Reddy *et al.* 1993) from different soil types of India. Soil application of sulphur along with vermicompost may improve the physical, chemical and biological properties of soil increase the yields of haulm, pod and kernel. (Suthar 2009), (Roddgiguer *et al.* 2012) and (Verma *et al.* 2013) support this finding. Due to S fertilization in addition to its multiple roles in metabolism as an essential constituent of amino acids and also improvement in vegetative structures and assimilated thereby maintaining balanced source-sink (Patel *et al.* 2009). So, accelerating the yield attributes viz. number of pods/plants, seed index and shelling percentage and ultimately increased the pod yield. Application of sulphur increased the yield mainly due to early flowering and greater pod setting. Improvement in haulm yield due to application of sulphur up to 45 kg/ha could be attributed to the higher plant growth and biomass production, possibly as a result of higher uptake of nutrients. Result of the present investigation is corroborating the finding of (Patel *et al* 2009), (Giri *et al.* 2011) and (Kader and Mona 2013) in groundnut. (Yadav *et al.* 2019) said that sulphur application through gypsum recorded the highest pod yield of groundnut as that obtained under SSP and

elemental sulphur treatment respectively. (Kumar *et al.* 2019) also reported that application of S increased the groundnut yield significantly.

**Plant Height:** Three years pooled data of plant height of groundnut (Table 4 revealed that all the treatment significantly increased the plant height as compared with T<sub>1</sub> (72.68 cm) treatment. Highest plant height (87.92 cm) was observed in treatment T<sub>12</sub> (RDF NPK + VC 6t/ha + S 45 kg/ha), which was at par with T<sub>5</sub> (RDF NPK+ VC 2t/ha + S 30 kg/ha), T<sub>6</sub> ((RDF NPK+ VC 2t/ha + S 45 kg/ha), T<sub>8</sub> ((RDF NPK+ VC 4t/ha + S 30 kg/ha), T<sub>9</sub> ((RDF NPK+ VC 4t/ha + S 45 kg/ha) and T<sub>11</sub> ((RDF NPK+ VC 6t/ha + S 30 kg/ha). Significantly lower plant height was recorded in T<sub>1</sub>, T<sub>2</sub> T<sub>3</sub>, T<sub>4</sub>, T<sub>7</sub> and T<sub>10</sub> as compared with T<sub>12</sub>. Increasing levels of vermicompost significantly increased the plant height as compared with each other. Soil application of sulphur through gypsum gradually increased the plant height, application of S 45 kg/ha along with VC 2, 4 and 6 t ha with RDF NPK recorded significantly higher plant height (84.78, 87.28 and 87.92 cm) as compare with S 15kg/ha (77.86, 80.54 and 81.16 cm) along with VC 2, 4 and 6 t/ha with RDF NPK. However, it was at par with S 30 kg /ha along with VC 2, 4 and 6 t/ha with RDF NPK. Organic sources of nutrients provide as all essential nutrients to plants resulted in rapid cell division, multiplication and cell elongation in meristematic region of the plants which promote vegetative growth of the plants (Patil *et al.* 2007). Increasing the plant height with increasing levels because due to S fertilization addition to its multiple roles in metabolism. As an essential constituent of amino acid and also improvement in vegetative structure and assimilates thereby maintaining balanced source-sink (Patil *et al.* 2009).

**Seed Index:** Three years pooled data on seed index of groundnut presented in Table 4 showed that highest seed index (41.81 gm) was recorded in T<sub>12</sub> (RDF NPK + VC 6t/ha+ S 45 kg/ha) which was statistically at par with T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub> and T<sub>11</sub>. Significantly lowest seed index was recorded in T<sub>1</sub> (68.91) over the treatment T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub>, T<sub>11</sub> and T<sub>12</sub>, While, it was at par with T<sub>2</sub> (RDF NPK + VC 4 t/ha) and rest of the treatment. Thus, an increase in number of pods/plants, kernels/pod and seed index as a result of sulphur application through gypsum might have been directly associated with the higher yield of groundnut crop. Thus, an increase in number of pods/plants, kernels/pod and seed index as a result of sulphur application through

gypsum might have been directly associated with the higher yield of groundnut crop. The increase in haulm yield may be the result of greater accumulation of dry matter under these sources of sulphur. A positive and significant correlation existed between pod yield and yield attributes and N, P and S uptake also provides an additional support for higher pod yield under these sources of sulphur. (Rao *et al.* 2013) found that application of sulphur at 45 kg/ha through gypsum recorded the highest number of filled pods/plant, 100-pod weight, 100-kernel weight and pod and haulm yields of groundnut. These results corroborate with the findings of (Kalaiyaran *et al.* 2002) and (Bagarama *et al.* 2012) in groundnut.

**Shelling Percentage (%):** The three years pooled data on shelling percentage of groundnut represented by Table 4 revealed that there is no significant difference was found on shelling percentage of groundnut. All the treatments where vermicompost and sulphur was applied (through gypsum) not significantly enhanced the shelling percentage of groundnut.

**Number of pods per plant:** Three years pooled data on number of pods per plant presented by Table 4 highest pods per plant (56.43) was observed in T<sub>12</sub> (RDF NPK + VC 6t/ha+ S 45 kg/ha). Soil application of VC 6 t/ha and sulphur application 45 kg/ha gave significantly higher pods per plant over treatments T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>7</sub> and T<sub>10</sub> but it was at par with T<sub>6</sub>, T<sub>8</sub>, T<sub>9</sub> and T<sub>11</sub>. T<sub>3</sub> (RDF NPK + VC 6t/ha) gave significantly higher number of pods per plant (46.57) as compared with T<sub>1</sub> (RDF NPK + VC 2t/ha), while, it was at par with T<sub>2</sub> (RDF NPK + VC 4t/ha). Soil application of S 45 kg/ha and VC 2, 4, and 6 t/ha (T<sub>6</sub>, T<sub>9</sub> and T<sub>12</sub>) gave significantly higher pod yield as compared with S 15 kg/ha and V C 2, 4 and 6 t/ha along with RDF NPK (T<sub>4</sub>, T<sub>7</sub> and T<sub>10</sub>) while, it was at par with T<sub>5</sub>, T<sub>8</sub> and T<sub>11</sub> respectively. The increased vegetative growth and the balanced C:N ratio might have increased the synthesis of carbohydrates, which ultimately promoted yield. The higher pod yield of groundnut might be due to cumulative effect of yield attributes such as number of pods, kernel pod-1 and weight of grains. These findings are in close conformity with those of (Malligawad 2010).

#### **Yield and Yield Attributes of Wheat:**

**Grain and Straw yield:** Three years pooled data (Table 3 and Fig. 2) of residual effect of vermicompost and sulphur (through gypsum) on grain and straw yield of wheat revealed that all

the treatments gave significantly higher yield of wheat as compared with T<sub>1</sub> (RDF NPK + VC 2 t/ha). Among the various tested combination higher grain and straw yield (50.23 and 71.07 q/ha) was recorded in treatment T<sub>12</sub> (RDF NPK + VC 6t/ha+ S 45 kg/ha). Soil application of VC 6t/ha + S 45kg/ha + RDF NPK in groundnut crop (T<sub>12</sub>) gave significantly higher grain and straw yield of wheat as compared with T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>7</sub> and T<sub>10</sub> and it was statistically at par with T<sub>5</sub> (RDF NPK+ VC 2t/ha + S 30 kg/ha) and rest of the treatment. The lowest yield of grain and straw was recorded in T<sub>1</sub> (RDF NPK + V C 2t/ha) 37.05 and 51.52 q/ha respectively. Graded increasing levels of V C (2 to 6 t /ha) gave significantly higher grain and straw yield as compared with each other like wise graded increasing levels of sulphur i.e. 15, 30and 45 kg/ha gave significantly higher yield as compared with each other under 2 and 4 t vermicompost was applied. While, it was giving significantly higher yield with application of sulphur 45 kg/ha and vermicompost 6 t/ha. It is clearly indicated that the increasing in yield of wheat might be due to residual effect of organic sources applied to groundnut as compared to other treatments. It is clearly indicated that the increasing in yield of wheat might be due to residual effect of organic sources applied to groundnut as compared to other treatments. These results are supported by the finding of (Rathore *et al.* 1995), who reported that residual effect of organic wastes (FYM) in combination with inorganic fertilizers was found to be significant on yield of succeeding wheat crops. The enhanced crop yield might be due to addition of nutrients and improvement in physical, chemical and biological properties of the soil by supplying organic matter through vermicompost. (Budher *et al.* 1991) reported that the application of organic manures in rice-wheat rotation resulted in higher rice yield due to residual effect of manures. (Ramawtar *et al.* 2013) also reported that 100 % RDF, vermicompost 2.0 t/ha and sulphur 60 kg/ha applied to cluster bean recorded significantly higher grain yield of succeeding wheat crop. Results of (Mohan *et al.* 2018) also favored these finding, they observed that application of 100 % RDF + 25 N through vermicompost obtained increasing yield of wheat than other treatments. (Singh *et al.* 2018) also reported that the improvement in yield of wheat crop was recorded with the application of 100% RDF + vermicompost (2t/ha) + PSB. (Mathukia *et al.* 2016) also support this finding they observed that RDF and vermicompost recorded significantly higher grain and straw yield of wheat.

**Table 1. Initial physico-chemical properties of experimental soil**

SI. N.	Physico-chemical Character	Value
1	pH	8.1
2	EC	0.18
3	Organic Carbon (%)	0.21
4	Available phosphorous (kg/ha)	51.0
5	Available potash (kg/ha)	159
6	Available sulphur (ppm)	7.1

**Table 2. Effect of sulphur and vermicompost on yield of wheat, groundnut, system wheat equivalent, net return and B:C ratio in Ground nut – wheat crop sequence. (Pooled of three years)**

S. N.	Treatments	Groundnut yield (q/ha)			wheat yield (q/ha)		SWEY (q/ha)	Net return	B:C
		Seed	Haulm	Kernel	Grain	Straw			
T1	vc2t/ha +NPK	30.52	43.60	20.89	37.05	51.52	140.72	192364	2.21
T2	vc4t/ha+NPK	32.72	47.19	22.61	40.30	56.62	151.41	203997	2.10
T3	vc6t/ha +NPK	35.20	50.56	24.53	43.61	60.25	163.14	217181	2.03
T4	vc2t/ha+15kg S/ha+NPK	34.62	49.79	23.93	42.08	58.52	159.64	229644	2.64
T5	vc2t/ha+30kg S/ha+NPK	39.33	55.26	27.51	46.33	65.33	179.85	269790	3.09
T6	vc2t/ha+45kg S/ha +NPK	40.42	58.24	28.35	47.85	68.82	185.09	279838	3.20
T7	vc4t/ha+15kg S /ha+NPK	37.01	52.28	25.80	44.48	62.55	170.10	240798	2.48
T8	vc4t/ha+30kg S /ha+NPK	41.37	57.11	29.36	47.81	67.53	188.19	276545	2.84
T9	vc4t/ha+45kg S /ha NPK	42.43	60.09	30.30	49.90	70.18	193.93	287289	2.95
T10	vc6t/ha+15kg S /ha+NPK	38.43	54.34	26.92	46.00	65.30	176.44	244009	2.28
T11	vc6t/ha+30kg S /ha+NPK	42.38	58.32	30.41	48.29	69.25	192.09	274067	2.55
T12	vc6t/ha+45kg S /ha+NPK	43.14	60.75	30.88	50.23	71.07	196.64	282721	2.63
S.Em±		0.81	1.11	0.56	0.89	1.25	2.94		
C.D.0.05%		2.29	3.15	1.59	2.52	3.52	8.29		

**Table 3. Effect of sulphur and vermicompost growth and yield attributes of groundnut in Groundnut- wheat crop sequence (Pooled of three years)**

S. N.	Treatments	Groundnut			
		Seed index	Plant height	Selling%	Pods/plant
T1	vc2t/ha +NPK	38.91	72.68	68.46	39.57
T2	vc4t/ha + NPK	39.43	75.79	69.13	43.60
T3	vc6t/ha +NPK	39.98	78.88	69.74	46.57
T4	vc2t/ha+15kg S/ha+NPK	39.90	77.86	69.18	45.63
T5	vc2t/ha+30kg S/ha+NPK	40.44	81.90	70.02	50.75
T6	vc2t/ha+45kg S/ha +NPK	41.01	84.78	70.79	53.48
T7	vc4t/ha+15kg S /ha+NPK	40.43	80.54	69.78	48.34
T8	vc4t/ha+30kg S /ha+NPK	40.97	84.34	70.70	51.91
T9	vc4t/ha+45kg S /ha NPK	41.35	87.28	71.43	54.89
T10	vc6t/ha+15kg S /ha+NPK	41.01	81.16	70.67	50.37
T11	vc6t/ha+30kg S /ha+NPK	41.51	85.24	71.23	54.49
T12	vc6t/ha+45kg S /ha+NPK	41.81	87.92	71.64	56.43
S.Em±		0.60	1.14	1.30	1.11
C.D. (0.05%)		1.71	3.22	3.66	3.13

**Table 4. Effect of sulphur and vermicompost on growth and yield attributes of wheat in Ground nut- wheat crop sequence (Pooled of three years)**

S. N.	Treatments	Test weight(g)	Plant height(cm)	Effective tiller/plant	Spike length (cm)
T1	vc2t/ha +NPK	45.39	90.07	5.59	9.79
T2	vc4t/ha+ NPK	45.93	93.98	6.82	10.56
T3	vc6t/ha +NPK	46.77	96.78	7.61	11.38
T4	vc2t/ha+15kg S/ha+NPK	46.33	95.18	6.88	10.31
T5	vc2t/ha+30kg S/ha+NPK	47.13	99.94	8.77	11.82
T6	vc2t/ha+45kg S/ha +NPK	48.04	103.02	8.91	11.92
T7	vc4t/ha+15kg S /ha+NPK	46.43	97.95	7.69	10.85
T8	vc4t/ha+30kg S /ha+NPK	47.69	101.71	8.89	11.62
T9	vc4t/ha+45kg S /ha NPK	48.42	104.37	9.61	12.28
T10	vc6t/ha+15kg S /ha+NPK	46.98	99.46	7.91	11.16
T11	vc6t/ha+30kg S /ha+NPK	48.50	102.83	9.06	11.95
T12	vc6t/ha+45kg S /ha+NPK	49.09	105.81	9.69	12.42
S.Em±		0.74	1.05	0.33	0.22
C.D. (0.05%)		2.10	2.98	0.94	0.61

**Table 5. Effect of sulphur and vermi-compost on total uptake of nutrient by groundnut and wheat in Ground nut - Wheat crop sequence (Pooled of three years)**

S. N.	Treatments	Groundnut (kg/ha)				Wheat (kg/ha)			
		N	P	K	S	N	P	K	S
T1	vc2t/ha +NPK	148.66	14.41	79.15	7.58	76.42	10.84	57.50	23.03
T2	vc4t/ha+NPK	174.82	16.09	88.36	8.95	89.22	12.60	64.24	27.67
T3	vc6t/ha +NPK	203.31	18.11	96.69	10.28	100.27	14.63	68.87	31.95
T4	vc2t/ha+15kg S/ha+NPK	188.93	17.70	93.70	10.05	92.83	13.30	68.07	31.88
T5	vc2t/ha+30kg S/ha+NPK	238.22	21.61	107.10	13.00	111.03	16.67	78.10	41.05
T6	vc2t/ha+45kg S/ha +NPK	261.21	23.82	115.52	15.05	119.72	18.03	84.50	47.00
T7	vc4t/ha+15kg S /ha+NPK	210.82	19.40	100.15	11.40	104.11	15.12	73.92	35.84
T8	vc4t/ha+30kg S /ha+NPK	256.10	23.12	114.36	14.53	117.79	17.73	82.94	43.58
T9	vc4t/ha+45kg S /ha NPK	278.90	25.30	121.75	16.58	128.15	18.99	85.73	48.21
T10	vc6t/ha+15kg S /ha+NPK	230.10	20.71	104.97	12.36	110.05	16.42	77.87	39.11
T11	vc6t/ha+30kg S /ha+NPK	266.64	24.31	118.67	14.84	122.53	18.27	85.66	45.26
T12	vc6t/ha+45kg S /ha+NPK	292.50	26.28	124.46	16.12	131.42	19.66	91.37	50.30
S.Em±		6.87	0.53	2.46	0.39	2.62	0.37	1.83	1.25
C.D. (0.05%)		19.39	1.50	6.93	1.10	7.40	1.03	5.17	3.54

**Table 6. Effect of sulphur and vermi-compost on physic-chemical properties of soil after harvest of groundnut and wheat crops (after three years)**

S. No.	Treatments	EC (1:2) (dS/m)	pH (1:2)	OC (%)	Available (kg/ha)	P <sub>2</sub> O <sub>5</sub>	Available K <sub>2</sub> O (kg/ha)	Available S (ppm)
T1	vc2t/ha +NPK	0.17	8.07	0.32	47.50		186.18	7.73
T2	vc4t/ha+NPK	0.20	8.03	0.35	49.12		189.08	8.93
T3	vc6t/ha +NPK	0.21	7.95	0.38	51.02		192.92	9.30
T4	vc2t/ha+15kg S/ha+NPK	0.19	7.94	0.32	48.50		187.32	9.46
T5	vc2t/ha+30kg S/ha+NPK	0.20	7.90	0.34	49.25		188.43	11.10
T6	vc2t/ha+45kg S/ha +NPK	0.21	7.85	0.35	50.67		189.10	13.27
T7	vc4t/ha+15kg S /ha+NPK	0.21	7.92	0.35	49.81		190.73	9.80
T8	vc4t/ha+30kg S /ha+NPK	0.21	7.90	0.36	50.46		191.60	11.47
T9	vc4t/ha+45kg S /ha NPK	0.22	7.88	0.36	50.60		192.07	13.47
T10	vc6t/ha+15kg S /ha+NPK	0.22	7.80	0.39	51.12		193.73	10.28
T11	vc6t/ha+30kg S /ha+NPK	0.23	7.77	0.40	51.19		194.37	12.29
T12	vc6t/ha+45kg S /ha+NPK	0.24	7.76	0.41	51.31		195.07	14.51
	S. Em±	0.02	0.08	0.01	1.09		2.04	0.48
	C. D. (0.05%)	0.06	0.23	0.04	3.20		5.98	1.43

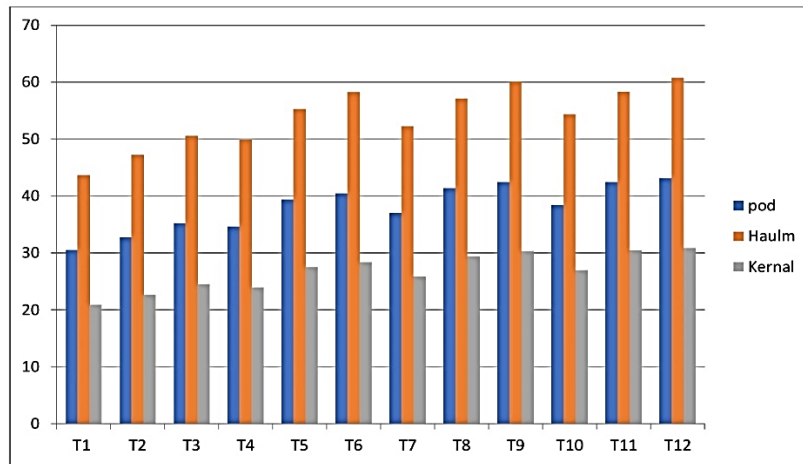


Fig. 1. Effect of sulphur and vermi-compost on pod, haulm and kernel yield (q/ha) of groundnut in Groundnut -wheat crop sequence (Pooled of three years)

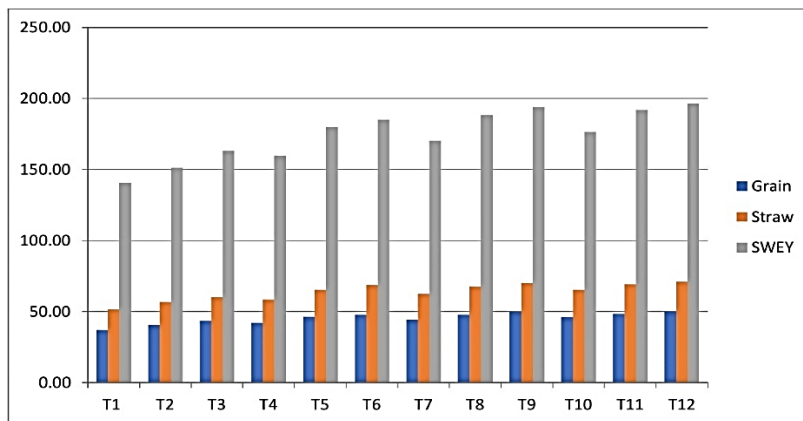


Fig. 2. Effect of sulphur and vermi-compost on grain, straw and system wheat equivalent yield (q/ha) of wheat in Groundnut -wheat crop sequence (Pooled of three years)

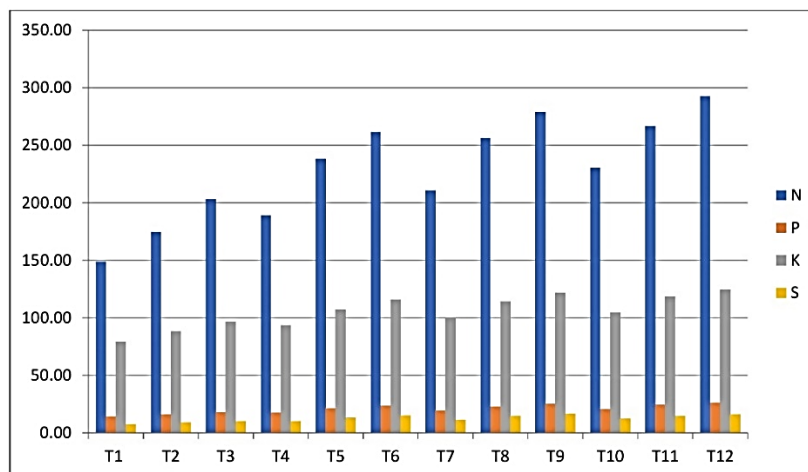
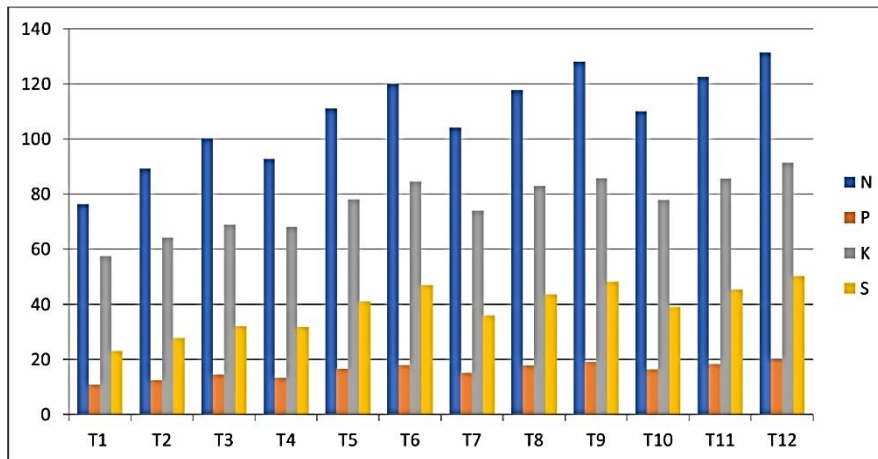


Fig. 3. Effect of sulphur and vermi-compost on total uptake of nutrient by wheat crop in Groundnut -Wheat crop sequence (Pooled of three years)



**Fig. 4. Effect of sulphur and vermi-compost on total uptake of nutrient by Ground nut crop Ground nut - Wheat crop sequence (Pooled of three years)**

**Plant Height:** The three years pooled data of plant height of wheat (Table 5) revealed that all the treatment significantly increased the plant height of wheat as compared with the T<sub>1</sub> (90.07) (RDF NPK + V C 2t/ha), highest plant height (105.81) was observed in T<sub>12</sub> which was at par with T<sub>5</sub> (RDF NPK + V C 2t/ha+ S 30 kg/ha), T<sub>6</sub> (RDF NPK + V C 2t/ha + S 45 kg/ha), T<sub>8</sub> (RDF NPK + V C 2t/ha + S 30 kg/ha), T<sub>9</sub> (RDF NPK + V C 4t/ha + S 45 kg/ha) and T<sub>11</sub> (RDF NPK + V C 6t/ha + S 30 kg/ha). Graded increasing levels of vermicompost (V C 2 to 6 t/ha) significantly increased the plant height as compared with each other. Increasing levels of sulphur (through gypsum) from 15 to 45 kg/ha significantly increased the plant height up to 15 to 30 kg/ha but it was at par with increasing levels of sulphur from 30 to 45 kg/ha. T<sub>1</sub> (RDF NPK + V C 2 t/ha), T<sub>2</sub> (RDF NPK + V C 4 t/ha), T<sub>3</sub> (RDF NPK + V C 6 t/ha), T<sub>4</sub> (RDF NPK + V C 2t/ha+ S 15 kg/ha), T<sub>7</sub> (RDF NPK + V C 4t/ha+ S 15 kg/ha) and T<sub>10</sub> (RDF NPK + V C 26t/ha+ S 15 kg/ha) recorded significantly lower plant height as compared with T<sub>12</sub> (RDF NPK + V C 6t/ha+ S 45 kg/ha). Vermicompost is organic manure, leave nutrients to the next crop and in case of sulphur significant residual responses had been obtained by workers like (Shivran *et al.* 2000) and (Sharma and Singh 2005). Thus, N, P, K fertilizers, vermicompost and sulphur contributed to improved grain yield of wheat by improving growth and yield attributes.

**Test Weight:** Three years pooled data presented in Table 5 depicted that highest test weight (49.09) was recorded in T<sub>12</sub> (RDF NPK + V C 6t/ha+ S 45 kg/ha) which was statistically at par

with T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub> and T<sub>11</sub>. Significantly lowest test weight was recorded under T<sub>1</sub> (RDF NPK + V C 2t/ha) over the treatment T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub> and T<sub>11</sub> While, it was statistically at par with T<sub>2</sub> (RDF NPK + V C 4t/ha), T<sub>3</sub> (RDF NPK+ V C 6t/ha) and T<sub>4</sub> (RDF NPK + V C 2t/ha + S 15kg/ha). Similar higher values of yield attributes with combined use of an inorganic + organic source of nutrients was reported by (Davari and Sharma 2012).

**Number of Effective Tillers Per Plant:** The three years pooled data (Table 5) revealed that highest number of effective tillers (9.78) per plant in wheat was recorded under T<sub>12</sub> (RDF NPK + V C 6t/ha+ S 45 kg/ha). Data presented in Table 5 also revealed that minimum number of effective tillers per plant (5.59) was recorded under T<sub>1</sub> (RDF NPK+ V C 2t/ha). T<sub>12</sub> gave significantly higher number of effective tillers per plant over T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>7</sub> and T<sub>10</sub>. However, it was at par with the T<sub>5</sub>, T<sub>6</sub>, T<sub>8</sub>, T<sub>9</sub> and T<sub>11</sub>. Graded increasing levels of vermicompost from 2 to 6 t/ha gave significantly higher number of effective tillers up to 4 t/ha but again increasing levels 4 to 6 t/ha along with RDF NPK statistically at par. : Application of sulphur 15, 30 and 45 kg/ha gave significantly higher number of effective tiller but response between 30 to 45 kg S ha<sup>-1</sup> was found statistically at par. (Kulkarni *et al.* 2018) also reported that the yield attributes also exhibited similar trend with a significantly increased response due to organic and inorganic treatments in groundnut and wheat respectively.

**Length of Spike (cm):** Results of three years pooled data on length of spike (Table 5) revealed

that significantly higher length of spike was obtained where, vermicompost was applied 6 t/ha along with RDF NPK and S 45 kg/ha, which is at par with T<sub>5</sub> where vermicompost was applied 2 t/ha along with RDF NPK and S 30 kg/ha. Soil application of vermicompost 6 t/ha and S 45 kg/ha along with RDF NPK (T<sub>12</sub>) gave significantly higher length of spike (11.56 cm) over treatment T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>7</sub> and T<sub>10</sub>. While, it was statistically at par with soil application of Vermicompost 2t/ha and S 30kg/ha along with RDF NPK (T<sub>5</sub>) and rest of the treatment. Lowest length of spike was (8.09) was recorded under T<sub>1</sub> (RDF NPK + V C 2 t/ha). The length of spike was found to be significant between 15 and 30 kg/ha S application but further increase in its levels from 30 to 45 kg/ha did not influence the length of spike significantly. Graded increasing levels of vermicompost increased the length of spike significantly among the vermicompost levels. (Sawan 2016) support this finding.

**Nutrient Uptake by Groundnut:** The lowest pooled total nutrient uptake by groundnut was recorded under application of vermicompost 2 t/ha along with RDF NPK (Fig. 3). Application of V C 6 t/ha and sulphur (through gypsum) 45 kg/ha along with RDF NPK treatment recorded the highest pooled total N, P, K and S uptake by groundnut and it was at par with T<sub>5</sub>, T<sub>6</sub>, T<sub>8</sub>, T<sub>9</sub> and T<sub>11</sub>. Significantly increased in the uptake of nutrient by groundnut was recorded under application of vermicompost (2, 4 and 6 t/ha). The uptake of nutrients N, P and K was found to be significant between 15 to 30 kg/ha of sulphur application but further increase in levels from 30 to 45 kg ha<sup>-1</sup> did not influence the nutrient uptake significantly. However, in case of total sulphur uptake it was found significant up to application of sulphur 45 kg ha<sup>-1</sup>. The uptake of nutrients N, P and K was found to be significant between 15 to 30 kg/ha of sulphur application but further increase in levels from 30 to 45 kg ha<sup>-1</sup> did not influence the nutrient uptake significantly. However, in case of total sulphur uptake it was found significant up to application of sulphur 45 kg ha<sup>-1</sup>. It might be due to the greater availability of nutrients in soil which enhanced the growth of plants and ultimately led to higher accumulation of nutrients in their parts along with the highest total uptake. The enhanced release of nutrients from the organic sources increased the nutrient uptake by groundnut crop. This might be ascribed to the increased availability of nutrient through organic sources, vermicompost and gypsum application. (Parihar and Pathan 2004) and (Roy and Singh 2006) reported that the

application of organic and fertilizers increased the nutrient uptake by wheat. This may be ascribed to the combined effect of organic and inorganic fertilizers on the increased nutrient availability and microbial activity resulting in better nutrient absorption and growth of crops. (Kumble *et al.* 2018) also support this finding that the highest soil available N, P, K and total uptake of N, P and K by crops were reported with application of general recommended dose to groundnut and wheat. (Mathivanan *et al.* (2013) also reported that vermicompost contain plant nutrients including N, P, K, Ca, Mn, Zn and Cu the uptake of which has a positive effect on plant nutrients, photosynthesis, chlorophyll content of leave and improves the nutrient content of different plant components. The positive influence of sulphur fertilization on nutrient concentration in crop seem to be due to improved nutritional environment both in rhizosphere and the plant system which led to greater translocation of N, P and S to reproductive parts which ultimately increased the concentration of these nutrients in pods and haulm. The increased availability of nutrients in root zone coupled with increased metabolic activity at cellular level might have increased the uptake of nutrients and their accumulation in various plant parts. Several workers have also reported increased N, P and S concentration and uptake due to S application (Kumar *et al.* 2008), (Thathe *et al.* 2008), (Jat and Ahlawat, 2009) and (Kadar and Mona, 2013).

**Nutrient Uptake by Wheat:** The represented by Fig. 4 revealed that significantly higher total pooled N, P, K and S uptake by wheat was recorded in application of V C 6 t/ha and sulphur 45 kg/ha along with RDF NPK as compared to rest of the treatments (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>7</sub> and T<sub>10</sub>). Application of vermicompost and sulphur 4 and 6 t/ha and 30 and 45 kg/ha along with RDF NPK to kharif groundnut treatments were at par with each other for total pooled N, P, and K uptake by wheat. The uptake of nutrients N, P and K was found to be significant between 15 to 30 kg S ha<sup>-1</sup> application but further increased in its levels from 30 to 45 kg S ha<sup>-1</sup> did not influence the nutrient uptake significantly. However, in case of S uptake it was found significant up to further increasing levels of sulphur from 30 to 45 kg S ha<sup>-1</sup> application along with RDF NPK. The uptake of nutrients N, P and K was found to be significant between 15 to 30 kg S ha<sup>-1</sup> application but further increased in its levels from 30 to 45 kg S ha<sup>-1</sup> did not influence the nutrient uptake significantly. However, in case of S

uptake it was found significant up to further increasing levels of sulphur from 30 to 45 kg S ha<sup>-1</sup> application along with RDF NPK. The higher uptake of N, P, K and S in the treatments receiving organic sources to groundnut could be due to the direct uptake of N, P, and K by leaves resulting in higher production of chlorophyll, dry matter and higher uptake of macronutrients by wheat. The increase in nutrients absorption might be due to more availability of nutrients in soil solution. An integrated application of organic and inorganic showed higher uptake of N, P and K compared to that of sole organic manures application due to the increased nutrients availability (Laxminarayana 2004).

#### Soil properties and available nutrient status after harvest of groundnut and wheat:

**Soil pH and Electrical Conductivity:** Result indicated that the pH of T<sub>1</sub> (RDF NPK and V C 2t/ha) where sulphur was not applied showed 8.07 pH (Table 6). The value of pH from T<sub>12</sub> (RDF NPK + V C 6 t/ha + S 45 kg/ha) where vermicompost and sulphur (through gypsum) application was used resulted to be the lowest pH 7.76 as compared to all other treatments. Significantly lowest soil pH was reported under RDF NPK + V C t/ha + S 45 kg/ha as compared to rest of the treatments. However, application of V C 6 t ha<sup>-1</sup> + S 15 and 30 kg ha<sup>-1</sup> + RDF NPK (T<sub>10</sub> and T<sub>11</sub>), were found to be non-significant with each with respect to soil pH. The EC of soil varies from 0.17 to 0.24 dSm<sup>-1</sup> and the highest EC of soil was registered in T<sub>12</sub> (RDF NPK + V C 6t/ha + S 45 kg/ha) as compared with T<sub>1</sub> (RDF NPK + V C 2t/ha) treatment. "The treatment T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub> and T<sub>11</sub> were on par with each other for soil ECe. In general, significant lower soil pH was recorded with addition of higher dose of vermicompost and sulphur as compared to lower dose of vermicompost and sulphur treatments. The release of organic acids during the process of decomposition may be attributed to decline in soil pH" (Amusan et al. 2011) and (kamble et al. 2018). The increase in EC of soil might be due to more solubilization of fixed nutrients (Mathiwala et al. 2013).

**Organic Carbon (%):** The data given in Table 6 revealed that organic carbon content of soil were significantly influenced due to different treatments after harvesting of crop. The maximum values of organic carbon (0.41 %) were recorded under T<sub>12</sub> (RDF NPK + V C t/ha+ S 45kg/ha), whereas minimum values of organic

carbon were observed under T<sub>1</sub> (RDF NPK + V C 2t/ha). Soil application of V C 6 t/ha + S 45 kg ha<sup>-1</sup> along with RDF NPK (T<sub>12</sub>) content significantly higher organic carbon as compared with T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub> and T<sub>9</sub> while it was at par with T<sub>10</sub> (RDF NPK + V C 6t/ha + S 15 kg/ha) and T<sub>11</sub> (RDF NPK + V C 6t/ha + S 30 kg/ha). Beneficial effect of organic source as well as integration of different sources of nutrients on soil fertility was also reported by various workers (Acharya et al. 1998), (Tiwari et al. 2002), (Sutaria et al. 2010) and (Basak et al. 2020).

**Available Nutrient Status:** Significantly highest poled soil available P was registered under application of vermicompost 6 t /ha and S 45 kg/ha along with RDF NPK over the treatment T<sub>1</sub>, T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub> and T<sub>9</sub> (Table 6). While, it was at par with T<sub>3</sub> (RDF NPK + V C 6 t/ha), T<sub>10</sub> (RDF NPK + V C 6t/ha + S 15 kg/ha) and T<sub>11</sub> (RDF NPK + V C 6t/ha + S 30 kg/ha). Significantly lowest soil available P was recorded in T<sub>1</sub> (RDF NPK + V C 2t/ha), However, the treatment T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub> and T<sub>9</sub> were on par with each other. Increasing levels of vermicompost 6t/ha found significant in available phosphorous as compared with 2 t/ha while it was at par with 4 t /ha V C along with RDF NPK. The soil available potassium (K) content was ranged from 186.18 to 195.07 kg/ha after harvest of wheat. However, the lowest soil available K content (186.18) was recorded under application of vermicompost 2 t/ha along with recommended dose of fertilizer N, P and K. Significantly highest (195.01 kg/ha) pooled soil available K was found in T<sub>12</sub> over the remaining treatments. (Table 6) except T<sub>3</sub>, T<sub>10</sub> and T<sub>11</sub> where, vermicompost was applied 6 t/ha and sulphur along with RDF NPK. The treatments T<sub>1</sub>, T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>, T<sub>8</sub> and T<sub>9</sub> were on par with each other. Increased in available K due to organic manures application may be attributed to direct addition of K to available pool of soil K. Significantly lowest (7.73 ppm) soil available S was recorded in T<sub>1</sub> (RDF NPK + V C 2t/ha) followed by T<sub>2</sub> and T<sub>3</sub> (8.93 and 9.30 ppm). Significantly highest soil available S after harvest of wheat was recorded in application of V C 6 t/ha and S 45 kg/ha along with RDF NPK as compared to other treatments. Available S was found significantly higher with increasing levels of sulphur (through gypsum) among the 15, 30 and 45 kg S ha<sup>-1</sup>, enhance in available S with increasing levels of S might be due to because gypsum is the direct sources of S in soil. Increasing levels of vermicompost 6t/ha found significant in available phosphorous as compared with 2 t/ha while it was at par with 4 t

/ha V C along with RDF NPK. The increasing in available P content of soil due to the incorporation of organic manures may be attributed to the direct addition of P as well as organic acids releasing during the decomposition of organic matter. Similar results were also obtained by (Kumar *et al.* 2003) and (Jamir *et al.* 2013) reported the improvement in available P status due to integrated use of organic manures with chemical fertilizer. "Increased in available K due to organic manures application may be attributed to direct addition of K to available pool of soil K. The beneficial effect of organic sources on available K might also be attributed to the reduction in fixation of and released of K due to interaction of organic matter with clay besides the direct K addition to the available K pool of soil" (Sharma *et al.* 2003). Similar finding reported by (Mathivanan *et al.* 2013) reported that the soil properties such as pH, EC, available nitrogen, phosphorous, potassium, iron, zinc, copper and manganese were found to vary in the soil treated with vermicompost application. Available S was found significantly higher with increasing levels of sulphur (through gypsum) among the 15, 30 and 45 kg S ha<sup>-1</sup>, enhance in available S with increasing levels of S might be due to because gypsum is the direct sources of S in soil. The application of vermicompost along with inorganic sulphur generally resulted in buildup of available S status of the soil. (Singh *et al.* 2012) in an incubation study observed an increase in the soil microorganism population apparently utilize organically bound S and converted it in to cystine and methionine, which are further converted into inorganic sulphate by microorganism. "The buildup of available S in soil with the addition of FYM and vermicompost after the harvest of crop has also been reported" (Nambiar and Ghosh 1984). "Application of sulphur along with different doses of NPK or vermicompost improved the soil health and increased availability of nutrients in the soil" (Solanki *et al.* 2020; Chaudhary *et al.*, 2005; Dash *et al.*, 2013).

**Wheat equivalent yield, economics and returns from cropping sequence:** Significantly highest wheat equivalent system yield (196.44 q/ha) was registered under application of V C 6 t/ha and S 45 kg/ha along with RDF N P K (T<sub>12</sub>) (Table 3). The lowest pooled wheat equivalent system yield (140.72 q/ha) was recorded under application V C 2t/ha along with RDF NPK (T<sub>1</sub>). From the data it is clearly visible that wheat equivalent system yield is at par with T<sub>8</sub>, T<sub>9</sub> and T<sub>11</sub>. The highest pooled net monetary return (Rs

287289) was obtained in T<sub>9</sub> (RDF NPK + V C 4t/ha + S 45 kg/ha). There was slightly higher B: C ratio (3:20) was obtained in treatment T<sub>6</sub> (RDF NPK + V C 2 t/ha + S 45 kg/ha) as compared with treatment T<sub>5</sub> where, 30 kg/ha sulphur was applied along with recommended dose of N, P, K and vermicompost 2t/ha. Hence treatment T<sub>5</sub> is recommended for sustainable groundnut- wheat crop production, getting higher net monetary return, B: C ratio and improvement of soil fertility in groundnut-wheat cropping sequence. Slightly higher B: C ratio was obtained in treatment T<sub>6</sub> as compared with treatment T<sub>5</sub> because gypsum is a cheaper source of sulphur nutrient (Yaday, 2019).

#### 4. CONCLUSIONS

Nutrient requirement varies with different crop in the system and if investigated systematically, may help to regulate the nutrient demands of the succeeding crops in terms of saving in fertilizers and changes in soil fertility use of chemical fertilizers has deleterious effect on soil which in turn cause decline in productivity, low nutrient recovery efficiency and increased in cost of production and environmental pollution.

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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