Nutrient Concentration and Their Uptake and Available Nutrients in Soil Influenced by Irrigation, Mulching and Integrated Nutrient Management in Summer Groundnut

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**Abstract**

An experiment was conducted to assess the effect of irrigation, mulching and integrated nutrient management on nutrient concentration and their uptake and available nutrients in summer groundnut during 2015 and 2016 at the Department of Agronomy, I.Ag.Sc, BHU, Varanasi. Results showed that application of irrigation at 100 mm CPE recorded highest N, K and S content, available nutrients in soil, kernel and haulm yield. However, irrigation at 60 mm CPE recorded significantly the highest P content, NPKS uptake, available nutrients in soil, kernel and haulm yield over 80 and 100mm CPE. Dust mulch recorded higher nutrient content and available nutrients in soil whereas, paddy straw mulch recorded maximum NPKS uptake, kernel and haulm yield. Among INM treatments, an application of 75%NPK +25N through FYM +60 kg sulphur through gypsum recorded significantly highest NPKS content and their uptake, available nutrients in soil, kernel and haulm yield as compared to other INM treatments.

**Keywords**

Available nutrients, Irrigation, INM, Mulching, Nutrient content and uptake.

**Introduction**

Groundnut (*Arachis hypogaea* L.) is the major *kharif* oilseeds crop of India. India ranks first in the world in respect of area and second in production after China. But the productivity (about 1000 kg/ha) of groundnut is quite low as compared to world average productivity (1500 kg/ha) primarily due to its cultivation in acidic soils with low N, P, Ca, S, B, inadequate organic matter (Noman et al., 2015), moisture stress at various growth stages irrespective of production environments, irrigation methods, varieties and other cultivation practices (Thiyagarajan et al., 2009). Under irrigated conditions, water use efficiency for this crop is low due to improper irrigation management.

The reduction in yield will be greater if severe stress occur during the critical crop growth stages like flowering and pod formation (Saha and Gunri, 2014). Thus the water management is most important factor because groundnut has specific moisture need due to the unique feature of developing the pods underground (Baliarsingh and Mahapatra, 2014). Proper irrigation scheduling helps the crop to put good crop growth and yield (Thiyagarajan et al., 2010). Application mulch materials can be of great use for conserving moisture, regulating soil temperature, improves infiltration, soil water retention, decreases bulk density and for suppression of weeds during early stages of
crop growth (Sounda et al., 2006). However, the effect varies with soils, climate, kind of mulch material used and the rate of application. The surface mulch favourably influences the soil moisture regime by controlling evaporation from the soil surface (Patel et al., 2017). Irrigation at critical stages and moisture conservation with mulching practices can increase the land and water productivity along with profitability (Ravisankar et al., 2014).

Groundnut is highly responsive to fertilizer application, although groundnut being a legume is capable of fixing atmospheric nitrogen, it responds to small quantity of nitrogenous fertilizer applied as starter dose (Chaudhary et al., 2015). It is an exhaustive crop and removes large amount of macro and micronutrients from soil. None of the sources of nutrient alone can meet the total plant nutrient need of crop adequately. Hence, integrated use of nutrients from chemical, organic, bio-fertilizer is the most efficient way to supply plant nutrients for sustained crop productivity and improved soil fertility (Mohapatra and Dixit, 2010 and Chavan et al., 2014). Keeping the above points in view, an experiment was conducted to study the combined effect of irrigation, mulching and INM on nutrient content, nutrient uptake and available nutrients in summer groundnut.

**Materials and Methods**

A field study was conducted during the summer season of 2015 and 2016 at Agronomy Farm, BHU, Varanasi (23°20’ N, 83°03’ E and 128.93 m above mean sea-level). The experimental soil was sandy clay loam with pH 7.86. The soil was low in available nitrogen (206.9 kg ha⁻¹) and available phosphorus (17.8 kg ha⁻¹) and medium in available potassium (233.1 kg ha⁻¹) and sulphur (15.6 kg ha⁻¹). Average values for bulk density 1.45 g cm⁻³, particle density 2.62 g cm⁻³, field capacity 19.6%, permanent wilting point 4.30% and EC were 0.181 dSm⁻¹. The experiment was conducted in split plot design with twenty four treatment combinations. The treatments consisted of three irrigation regimes (I₁- 60 mm CPE, I₂- 80 mm CPE and I₃- 100 mm CPE) and two mulch treatments [M₁- paddy straw mulch and M₂- dust mulch] in the main plots and four INM levels (N₁- 100% NPK, N₂- 75% NPK+ 25% N through FYM+ 20 kg S through gypsum, N₃- 75% NPK+ 25% N through Vermicompost+ 40 kg S through gypsum and N₄- 75% NPK+ 25% N through FYM+ 60 kg S through gypsum in sub plots. The experiment was replicated three times. Keeping irrigation frequency constant predetermined quantity of water was applied by using Parshall flume. The entire quantity of nutrients as per treatment was applied in at sowing. Groundnut variety HG 37 was sown at row distance of 30x10 cm manually on 25 March 2015 and 10 March 2016. CPE was worked out from the daily Epan data taken from institute observatory. Irrigation was applied to crop at 60, 80 and 100 CPE as per treatment.

The experiment was repeated on the fixed site in the second year. All the general crop management practices were followed to the crops. The crop was harvested by hand on 29th May, 2015 and 20th May, 2016, when about 70% of haulms were dry. Observations on kernel and haulm yield were recorded at harvest of crop. The soil samples were taken from each plot at 0-15 cm depth at sowing and after harvesting of groundnut crop for the analysis of nutrient concentration in plant and available nutrients in soil as per the standard procedure. The available nutrients in soil (kg ha⁻¹) were calculated by multiplying the nutrient content and weight of soil (0-15 cm). Nutrient uptake (kg ha⁻¹) was calculated by
multiplying their nutrient concentration with crop yield. All the experimental data were analysed statistically to draw a valid conclusion.

**Results and Discussion**

**Nutrient content**

In groundnut, irrigation regimes and mulching did not affect significantly the total N, P, K and S contents (Table 1). However, N, K and S contents decreased with increasing number of irrigation and moisture availability, which was mainly due to dilution effect as a consequence of increased dry matter production. The higher P content in kernels and haulms was recorded with irrigation at 60 mm CPE and in paddy straw mulching. Results are corroborated with the findings of Singh et al., (2006) and Verma et al., (2012). Nutrients concentration in kernels and haulms increased with increasing nutrients level and more so with application of 75% NPK+ 25% N through FYM + 60 kg S through gypsum as compared to other INM treatments. This might be due to increased availability in presence of FYM, vermicompost and the synergy between nutrients. The results corroborate the finding of Arunachalam et al., (2012) and Noman et al., (2016).

**Nutrient uptake**

Nutrients uptake by groundnut significantly influenced by irrigation regimes, mulching and INM (Table 2 and 3). Irrigation at 60 CPE and paddy straw mulch recorded maximum N, P, K and S uptake by kernels, haulms and the total nutrients uptake. Better soil moisture conditions prevailing in these treatments could have facilitated more uptake of nutrients. Research results are corroborated with the research findings of Verma et al., (2015). In INM treatments, application of 75% NPK+ 25% N through FYM + 60 kg S through gypsum recorded significantly highest N, P, K and S uptake followed by 75% NPK+ 25% N through vermicompost+ 40 kg S through gypsum, 75% NPK+ 25% N through FYM+ 20 kg S through gypsum and100% NPK, respectively during both the years. Higher uptake was due to the higher dry matter production and higher nutrient content in different parts of plants, which corroborated the findings of Mohapatra and Dixit (2010) and Yadav et al., 2015. The higher uptake of plant nutrients due to application of the organic manures was reflected in the trend of growth and yield performance of the crop Choudhary et al., (2011) and Patra et al., (2011). Noman et al., (2014) reported the increase in S-uptake from 66.3 to 92.4% due to application of 20 and 40kg S ha\(^{-1}\) over control, respectively. Increase in P uptake was due to increase in P availability from applied fertilizer and inherent soil source and combined effect of released organic acids and organic anions on decomposition of farmyard manure in acid lateritic soil (Dutta and Mondal, 2006, and Vishwakarma et al., 2012).

**Available nutrients**

**OC, EC and soil pH**

Effect of irrigation regimes, mulching and INM on pH, organic carbon (OC) and electrical conductivity was found to be non-significant (Table 4). However, it was slightly higher under 100 mm CPE and with dust mulch. Paddy straw mulch recorded lower pH and EC and the OC over dust mulch. This was due to fact that residue when left on soil surface and after decomposition increased the organic carbon which lowers down the electrical conductivity and soil pH (Monsefi et al., 2016). Amongst INM treatments, 75% NPK+ 25% N through FYM + 60 kg S through gypsum recorded highest pH, organic carbon and electrical conductivity than other INM treatments.
Table 1: Effect of irrigation regimes, mulching and integrated nutrient management on N, P and K content in kernel and haulm.

| Treatment | N content in kernel (%) | N content in Haulm (%) | P content in kernel (%) | P content in Haulm (%) | K content in kernel (%) | K content in Haulm (%) | S content in kernel (%) | S content in Haulm (%) |
|-----------|-------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
|           | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| I₁ | 3.15 | 3.09 | 1.45 | 1.42 | 0.33 | 0.32 | 0.117 | 0.115 | 1.05 | 1.00 | 1.17 | 1.15 | 0.186 | 0.175 | 0.117 | 0.113 |
| I₂ | 3.24 | 3.18 | 1.49 | 1.46 | 0.30 | 0.29 | 0.113 | 0.111 | 1.07 | 1.02 | 1.20 | 1.18 | 0.190 | 0.179 | 0.119 | 0.115 |
| I₃ | 3.21 | 3.15 | 1.46 | 1.43 | 0.32 | 0.31 | 0.115 | 0.113 | 1.06 | 1.01 | 1.19 | 1.17 | 0.189 | 0.178 | 0.117 | 0.113 |

SEm± NS

CD (P=0.05) NS

M₁ | 3.16 | 3.10 | 1.46 | 1.43 | 0.33 | 0.32 | 0.114 | 0.112 | 1.05 | 1.00 | 1.18 | 1.16 | 0.190 | 0.179 | 0.117 | 0.113 |
| M₂ | 3.24 | 3.18 | 1.48 | 1.45 | 0.31 | 0.30 | 0.116 | 0.114 | 1.06 | 1.01 | 1.19 | 1.17 | 0.191 | 0.180 | 0.119 | 0.115 |
| SEm± NS

CD (P=0.05) NS

N₁ | 3.16 | 3.10 | 1.41 | 1.38 | 0.30 | 0.29 | 0.113 | 0.111 | 1.03 | 0.98 | 1.15 | 1.13 | 0.178 | 0.167 | 0.115 | 0.112 |
| N₂ | 3.21 | 3.15 | 1.43 | 1.40 | 0.31 | 0.30 | 0.114 | 0.112 | 1.05 | 1.00 | 1.16 | 1.14 | 0.185 | 0.174 | 0.116 | 0.113 |
| N₃ | 3.20 | 3.14 | 1.49 | 1.46 | 0.32 | 0.31 | 0.116 | 0.114 | 1.06 | 1.01 | 1.21 | 1.19 | 0.191 | 0.180 | 0.119 | 0.115 |
| N₄ | 3.24 | 3.18 | 1.53 | 1.50 | 0.33 | 0.32 | 0.118 | 0.116 | 1.09 | 1.04 | 1.23 | 1.21 | 0.193 | 0.181 | 0.121 | 0.117 |
| SEm± NS

CD (P=0.05) NS

I₁ - irrigation at 60 mm CPE, I₂ - irrigation at 80 mm CPE, I₃ - irrigation at 100 mm CPE, M₁ - paddy straw mulch, M₂ - dust mulch, F₁ - 100% NPK, F₂ - 75% NPK+25% N through FYM+20 kg S through gypsum, F₃ - 75% NPK+25% N through Vermicompost+40 kg S through gypsum, F₄ - 75% NPK+25% N through FYM+60 kg S through gypsum.
Table 2: Effect of irrigation regimes, mulching and integrated nutrient management on N, P and K uptake in grain and straw

| Treatment | N uptake in Kernel (kg ha\(^{-1}\)) | N uptake in Haulm (kg ha\(^{-1}\)) | P uptake in Kernel (kg ha\(^{-1}\)) | P uptake in Haulm (kg ha\(^{-1}\)) | K uptake in Kernel (kg ha\(^{-1}\)) | K uptake in Haulm (kg ha\(^{-1}\)) | S uptake in Kernel (kg ha\(^{-1}\)) | S uptake in Haulm (kg ha\(^{-1}\)) |
|-----------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
|           | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Irrigation regimes | | | | | | | | | | | | | | |
| I\(_1\) | 57.9 | 63.0 | 59.0 | 60.1 | 6.07 | 6.52 | 4.76 | 4.87 | 19.3 | 20.4 | 47.6 | 48.7 | 3.42 | 3.57 | 4.76 | 4.78 |
| I\(_2\) | 57.7 | 61.0 | 58.4 | 58.8 | 5.75 | 6.00 | 4.60 | 4.64 | 19.0 | 19.5 | 47.6 | 48.1 | 3.39 | 3.44 | 4.68 | 4.64 |
| I\(_3\) | 55.6 | 59.2 | 58.3 | 58.3 | 5.15 | 5.40 | 4.42 | 4.44 | 18.4 | 19.0 | 46.9 | 47.2 | 3.26 | 3.33 | 4.65 | 4.60 |
| SEM± | 0.72 | 1.04 | 0.19 | 0.37 | 0.17 | 0.27 | 0.07 | 0.10 | 0.15 | 0.15 | 0.27 | 0.80 | 0.06 | 0.06 | 0.03 | 0.03 |
| CD (P=0.05) | 2.13 | 3.11 | 0.58 | 1.09 | 0.51 | 0.78 | 0.20 | 0.29 | 0.45 | 1.21 | 0.82 | 2.39 | 0.18 | 0.19 | 0.10 | 0.09 |
| Mulch | | | | | | | | | | | | | | | |
| M\(_1\) | 57.7 | 63.6 | 58.8 | 60.6 | 5.70 | 6.10 | 4.61 | 4.75 | 19.3 | 20.5 | 47.3 | 49.2 | 3.43 | 3.63 | 4.73 | 4.79 |
| M\(_2\) | 56.4 | 58.5 | 58.5 | 57.8 | 5.62 | 5.84 | 4.57 | 4.55 | 18.5 | 18.6 | 47.3 | 46.7 | 3.28 | 3.27 | 4.59 | 4.69 |
| SEM± | 0.41 | 1.03 | 0.09 | 0.33 | 0.14 | 0.23 | 0.06 | 0.07 | 0.12 | 0.37 | 0.24 | 0.71 | 0.04 | 0.05 | 0.03 | 0.02 |
| CD (P=0.05) | 1.22 | 3.08 | 0.26 | 1.02 | 0.43 | 0.67 | 0.19 | 0.22 | 0.34 | 1.09 | 0.74 | 2.14 | 0.13 | 0.15 | 0.08 | 0.07 |
| Nutrient management | | | | | | | | | | | | | | | |
| F\(_1\) | 51.3 | 54.4 | 52.6 | 53.8 | 4.91 | 5.12 | 4.21 | 4.32 | 16.7 | 17.2 | 42.9 | 44.0 | 2.91 | 2.97 | 4.29 | 4.36 |
| F\(_2\) | 55.1 | 59.5 | 55.9 | 55.8 | 5.36 | 5.70 | 4.45 | 4.47 | 18.0 | 18.9 | 45.3 | 45.5 | 3.20 | 3.32 | 4.51 | 4.53 |
| F\(_3\) | 58.7 | 63.0 | 60.9 | 61.2 | 5.91 | 6.24 | 4.74 | 4.78 | 19.5 | 20.3 | 49.5 | 49.9 | 3.53 | 3.64 | 4.82 | 4.87 |
| F\(_4\) | 63.1 | 67.4 | 65.0 | 65.7 | 6.47 | 6.81 | 5.01 | 5.08 | 21.3 | 22.1 | 52.3 | 53.0 | 3.79 | 3.87 | 5.12 | 5.14 |
| SEM± | 0.33 | 0.93 | 0.06 | 0.28 | 0.11 | 0.17 | 0.05 | 0.05 | 0.07 | 0.26 | 0.21 | 0.65 | 0.03 | 0.03 | 0.02 | 0.01 |
| CD (P=0.05) | 0.97 | 2.78 | 0.19 | 0.85 | 0.32 | 0.52 | 0.14 | 0.16 | 0.22 | 0.76 | 0.62 | 1.96 | 0.08 | 0.10 | 0.06 | 0.04 |

I\(_1\)-irrigation at 60 mm CPE, I\(_2\)-irrigation at 80 mm CPE, I\(_3\)-irrigation at 100 mm CPE, M\(_1\)-paddy straw mulch, M\(_2\)-dust mulch, F\(_1\)-100% NPK, F\(_2\)-75% NPK+25% N through FYM+20 kg S through gypsum, F\(_3\)-75% NPK+25% N through Vermicompost+40 kg S through gypsum, F\(_4\)-75% NPK+25% N through FYM+60 kg S through gypsum.
Table 3 Effect of irrigation regimes, mulching and integrated nutrient management on N, P K and S uptake

| Treatment                                      | Total uptake of N (kg ha\(^{-1}\)) | Total uptake of P (kg ha\(^{-1}\)) | Total uptake of K (kg ha\(^{-1}\)) | Total uptake of S (kg ha\(^{-1}\)) |
|------------------------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
|                                                 | 2015     | 2016     | 2015     | 2016     | 2015     | 2016     | 2015     | 2016     |
| Irrigation regimes                              |         |          |          |          |          |          |          |          |
| Irrigation at 60 mm CPE                         | 116.9    | 123.1    | 10.83    | 11.39    | 66.9     | 69.1     | 8.18     | 8.42     |
| Irrigation at 80 mm CPE                         | 116.1    | 119.8    | 10.35    | 10.64    | 66.6     | 67.6     | 8.07     | 8.15     |
| Irrigation at 100 mm CPE                        | 113.9    | 117.5    | 9.57     | 9.84     | 65.3     | 66.2     | 7.91     | 8.00     |
| SEm±                                            | 0.99     | 1.07     | 0.24     | 0.34     | 0.15     | 0.20     | 0.09     | 0.09     |
| CD (P=0.05)                                     | 2.96     | 3.21     | 0.70     | 1.00     | 0.46     | 0.59     | 0.26     | 0.28     |
| Mulch                                           |         |          |          |          |          |          |          |          |
| Paddy straw mulch (10 t ha\(^{-1}\))           | 116.4    | 124.0    | 10.31    | 10.85    | 66.7     | 69.8     | 8.19     | 8.42     |
| Dust mulch                                      | 114.8    | 116.1    | 10.19    | 10.39    | 65.9     | 65.4     | 7.90     | 7.96     |
| SEm±                                            | 0.53     | 0.70     | 0.20     | 0.14     | 0.12     | 0.15     | 0.08     | 0.06     |
| CD (P=0.05)                                     | 1.56     | 2.10     | NS       | 0.45     | 0.37     | 0.46     | 0.25     | 0.19     |
| Nutrient management                             |         |          |          |          |          |          |          |          |
| 100% NPK                                        | 103.8    | 108.1    | 9.10     | 9.43     | 59.5     | 61.1     | 7.21     | 7.34     |
| 75% NPK + 25% N through FYM+ 20 kg S through gypsum | 110.9    | 115.2    | 9.79     | 10.16    | 63.2     | 64.3     | 7.72     | 7.86     |
| 75% NPK+ 25% N through vermicompost+ 40 kg S through gypsum | 119.5    | 124.1    | 10.63    | 11.01    | 68.9     | 70.1     | 8.36     | 8.52     |
| 75% NPK + 25% N through FYM + 60 kg S through gypsum | 128.0    | 133.0    | 11.46    | 11.88    | 73.5     | 75.0     | 8.92     | 9.02     |
| SEm±                                            | 0.32     | 0.31     | 0.16     | 0.12     | 0.09     | 0.13     | 0.05     | 0.04     |
| CD (P=0.05)                                     | 0.96     | 0.92     | 0.45     | 0.37     | 0.26     | 0.38     | 0.17     | 0.11     |

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Table 4 pH, EC and bulk density after harvest as influenced by irrigation regimes, mulching, integrated nutrient management on summer groundnut

| Treatments                           | pH  | EC (dS m$^{-1}$) | Organic carbon (%) | Kernel yield (kg ha$^{-1}$) | Pod yield (kg ha$^{-1}$) |
|--------------------------------------|-----|-----------------|--------------------|-----------------------------|-------------------------|
|                                      | 2015| 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| Irrigation regimes                   |     |      |      |      |      |      |      |      |
| Irrigation at 60 mm CPE              | 7.85| 7.78 | 0.188| 0.178| 0.354| 0.360| 1839 | 2038 |
| Irrigation at 80 mm CPE              | 7.86| 7.79 | 0.187| 0.175| 0.352| 0.356| 1796 | 1935 |
| Irrigation at 100 mm CPE             | 7.86| 7.79 | 0.188| 0.177| 0.350| 0.352| 1715 | 1863 |
| CD (P=0.05)                          | NS  | NS   | NS   | NS   | NS   | NS   | 31.4 | 35.3 |
| Mulching                             |     |      |      |      |      |      |      |      |
| Paddy straw mulch (10 t ha$^{-1}$)  | 7.85| 7.78 | 0.182| 0.172| 0.353| 0.359| 1827 | 2051 |
| Dust mulch                           | 7.86| 7.80 | 0.197| 0.190| 0.350| 0.354| 1740 | 1840 |
| CD (P=0.05)                          | NS  | NS   | NS   | NS   | NS   | NS   | 25.6 | 28.8 |
| Nutrient management                  |     |      |      |      |      |      |      |      |
| 100% NPK                             | 7.86| 7.79 | 0.185| 0.174| 0.349| 0.354| 3729 | 3895 |
| 75% NPK + 25% N through FYM + 20 kg S through gypsum | 7.85| 7.80 | 0.184| 0.173| 0.352| 0.357| 3906 | 3987 |
| 75% NPK + 25% N through vermicompost + 40 kg S through gypsum | 7.85| 7.80 | 0.184| 0.173| 0.351| 0.355| 4090 | 4190 |
| 75% NPK + 25% N through FYM + 60 kg S through gypsum | 7.86| 7.79 | 0.186| 0.175| 0.353| 0.360| 4248 | 4377 |
| CD (P=0.05)                          | NS  | NS   | NS   | NS   | NS   | NS   | 4.2  | 6.5  |
| Initial Value                        | 7.89| 7.82 | 0.186| 0.176| 0.355| 0.361| -    | -    |
Table 5 Available N, P, K and S after harvest as influenced by irrigation, mulching and integrated nutrient management

| Treatments | Available N (kg ha\(^{-1}\)) 2015 | Available N (kg ha\(^{-1}\)) 2016 | Available P (kg ha\(^{-1}\)) 2015 | Available P (kg ha\(^{-1}\)) 2016 | Available K (kg ha\(^{-1}\)) 2015 | Available K (kg ha\(^{-1}\)) 2016 | Available S (kg ha\(^{-1}\)) 2015 | Available S (kg ha\(^{-1}\)) 2016 |
|------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Irrigation regimes |                                  |                                 |                                 |                                 |                                 |                                 |                                 |                                 |
| Irrigation at 60 mm CPE | 197.8                           | 201.4                           | 16.1                            | 17.8                            | 230.2                           | 232.3                           | 14.5                            | 14.7                            |
| Irrigation at 80 mm CPE | 199.7                           | 202.7                           | 16.8                            | 19.1                            | 231.6                           | 234.7                           | 16.0                            | 16.2                            |
| Irrigation at 100 mm CPE | 200.7                           | 203.4                           | 17.6                            | 19.7                            | 233.8                           | 235.6                           | 16.2                            | 16.8                            |
| SEM± | 0.65                             | 0.45                             | 0.21                            | 0.35                            | 0.74                             | 0.48                             | 0.07                            | 0.08                            |
| CD (P=0.05) | 1.95                             | 1.36                             | 0.63                            | 1.07                            | 2.20                             | 1.42                             | 0.23                            | 0.25                            |
| Mulch |                                  |                                 |                                 |                                 |                                 |                                 |                                 |                                 |
| Paddy straw mulch (10 t ha\(^{-1}\)) | 198.1                           | 201.3                           | 16.4                            | 17.9                            | 229.9                           | 232.5                           | 15.1                            | 15.5                            |
| Dust mulch | 200.6                           | 203.6                           | 17.1                            | 19.8                            | 233.1                           | 235.9                           | 16.0                            | 16.2                            |
| SEM± | 0.58                             | 0.40                             | 0.19                            | 0.31                            | 0.66                             | 0.43                             | 0.06                            | 0.07                            |
| CD (P=0.05) | 1.74                             | 1.21                             | 0.56                            | 0.95                            | 1.96                             | 1.27                             | 0.21                            | 0.22                            |
| Nutrient management |                                  |                                 |                                 |                                 |                                 |                                 |                                 |                                 |
| 100% NPK | 196.6                           | 199.2                           | 16.4                            | 18.3                            | 230.1                           | 233.4                           | 13.7                            | 14.9                            |
| 75% NPK+ 25% N through FYM+ 20 kg S through gypsum | 198.7                           | 200.6                           | 16.6                            | 18.5                            | 230.3                           | 233.9                           | 15.8                            | 16.0                            |
| 75% NPK+ 25% N through vermicompost+ 40 kg S through gypsum | 200.2                           | 204.9                           | 16.9                            | 19.3                            | 232.4                           | 234.5                           | 16.1                            | 16.2                            |
| 75% NPK+ 25% N through FYM+ 60 kg S through gypsum | 202.2                           | 205.3                           | 17.1                            | 19.5                            | 233.2                           | 234.9                           | 16.6                            | 16.5                            |
| SEM± | 0.46                             | 0.16                             | 0.08                            | 0.11                            | 0.20                             | 0.19                             | 0.02                            | 0.03                            |
| CD (P=0.05) | 1.37                             | 0.47                             | 0.25                            | 0.31                            | 0.58                             | 0.55                             | 0.07                            | 0.09                            |
| Initial Value | 202.0                           | 199.7                           | 18.8                            | 16.8                            | 233.5                           | 232.6                           | 15.5                            | 15.6                            |
Available N, P, K and S in soil

Increased frequency of irrigation significantly decreased the available N, P, K and S in soil and it was found to be the highest with the irrigation at 100 mm CPE. The reason could be that insufficient moisture under this treatment did not support the adequate uptake of N, P, K and S by crop and most of these nutrients were left in the soil. Results are corroborated with the research findings of Verma et al., (2012). Dust mulch resulted significantly higher available N, P, K and S compared to paddy straw mulch. This is because of lower crop yield and poor utilization of nutrients under this treatment by groundnut. Higher amount of available N, P, K and S was recorded with 75% NPK+ 25% N through FYM + 60 kg S through gypsum.

Increase in available N, P, K and S due to organic manure FYM, vermicompost and chemical fertilizers application may be attributed to the direct addition of these nutrients to the available pool of soil. The favourable effect of organic manure and chemical fertilizers in enhancing the availability of nutrients in soil was also reported by Singh et al., (2006) and Mohapatra and Dixit (2010).

The build-up of soil available nutrients may also be attributed to the addition of FYM and vermicompost for the conversion of organically bound nutrients to inorganic forms and helped in the mineralization of soil nutrients leading to build-up of higher available nutrients. Varalakshmi et al., (2005) had reported increase in N content of soil with integrated nutrient management in groundnut. Incorporation of farmyard manure, lime and P fertilizer reduced the fixation of water soluble P and increased the mineralization of organic P due to microbial action which resulted in increase in available P in soil. An increase in K availability probably was from K bearing minerals by the organic acids released as a decomposition of FYM as reported by Singh et al., (2006).

Kernel and haulm yield

The significantly highest kernel and haulm yield was achieved under irrigation at 60 mm CPE followed by irrigation at 80 mm and 100 mm CPE, respectively (Table 4). The better development of crop under irrigated treatments was a result of better moisture availability, which maintained the internal water balance of the plant. Increase in yield is due to the increase in the yield attribute reported by Gupta et al., (2015). Paddy straw mulch recorded significantly higher kernel and haulm yield as compared to dust mulch. The better development of crop under paddy straw mulch treatment was a result of better moisture availability, which maintained the internal water balance of the plant. Increase in yield is due to the increase in the yield attribute reported by Ravisankar et al., (2014). Among INM treatments, an application of 75% NPK+ 25% N through FYM + 60 kg S through gypsum recorded significantly the highest kernel and haulm yield followed by 75% NPK+ 25% N through vermicompost + 40 kg S through gypsum as compared to other INM treatments. These results are corroborated with the research results of Vishwakarma et al., (2012), Chavan et al., (2014) and Patil et al., (2017).

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