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Effect of Tillage and Integrated Nutrient Management on Yield and Nutrient Uptake in Groundnut (*Arachis hypogaea* L.)

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ABSTRACT: The resource degradation in arid region is much faster than other ecosystem due to aberrant climatic conditions and anthropogenic activities. Agricultural productivity in the arid regions is very low and it is further intensified with the inappropriate crop management practices. Therefore, a two year study was conducted to evaluate the efficient tillage and nutrient management practices and their influence on crop yield and nutrient uptake in groundnut. The treatment comprises combinations of three tillage practices in main plots and six fertilizer management options in sub plots. Total of 18 treatment combinations were laid out in split plot design and replicated four times. Deep tillage produced significantly higher yield and yield attributes as compared to minimum tillage and also recorded higher nutrient uptake compared to minimum tillage. Among nutrient management options RDF along with seed inoculation with PSB and AMF recorded significantly higher attributes of yield and pod yield compared to RDF without seed inoculation.This treatment also recorded the maximum N, P, K uptake over rest of nutrient management practices. Thus, deep tillage along with RDF + PSB + AMF (4 kg ha^{-1}) enhanced yield and yield attributes as well as uptake of nutrients by groundnut. Our results showed that deep tillage along with integrated nutrient management options found profitable as compared to other combinations and it can be replicated in the arid domain for higher productivity.

Keywords: Biofertilizer, groundnut, nutrient uptake, tillage, yield.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is cultivated in dry regions with high variability of drought, temperature, rainfall and land degradation. India is the 2nd largest producer and next to China and ranks first in acreage. The productivity of groundnut is quite low mainly due to rain dependency (80%), monoculture (60%) and cultivation on degraded soils. Like other crops groundnut also needs sufficient amount of nutrients and water for sustainable production. Groundnut is used for both human and animal consumption and is an important source of concentrates (proteins, minerals and vitamins) and fibres.In conventional tillage, soil is mechanically agitated so as to loosen the soil for the growth of plant roots, which in turn makes the soil vulnerable to erosion, reduces the ability to hold water and looses lots of nutrients like nitrogen. Groundnut is an exhaustive crop and removes large amount of macro and micro-nutrients from soil which cannot be met by single nutrient source. The supply of nutrients through, combined application of biofertilizer, organic and inorganic sources has been found to be the best option for increasing productivity and maintaining sustainability, and hence there is ample scope of increasing productivity through combined use of various nutrient sources (Patil *et al*. 2017).

Biofertilizers are described as substances containing live microorganisms (useful bacteria and fungi) that are applied to seeds, plant surfaces, or roots (Macik *et al.* 2020; Suhag, 2016). Biofertilizers are classified into three categories: nitrogen-fixing, phosphorous solubilizing and mobilizing, and micronutrient biofertilizers (Raimi *et al*. 2017). Biofertilizers are an eco-friendly approach for mobilising/supplying nutrients to crop plants (Walkiewicz *et al*. 2020) and are used to supplement the chemical fertilizers to ensure sustainable agricultural production in recent years. Biofertilizers are always known to improve soil health, increase availability of mineral nutrients for plants, and stimulate plant growth through different mechanisms connected with microbial activity (Ellafi *et al*. 2011; Cisse *et al.* 2019; Basu *et al*. 2021). Judicial use of fertilizer is necessary for increasing agricultural production and reducing deleterious effects on soil. A balanced fertilizer means not only the use of major and secondary nutrients, but also other essential micronutrients and use of biofertilizers in correct proportions. Bhardwaj *et al*., 2014 realized the importance of useful aspects of biofertilizers and implementation of its application to modern agricultural practices. Improving crop yields due to use of bio-inoculants *viz*., *Arbuscular Mycorrhizal* Fungi (AMF), *Rhizobium*, *Azotobacter* and phosphate solubilizing bacteria (PSB) along with chemical fertilizers have been reported worldwide (Reddy *et al*. 2016). This study was conducted to examine the effect of phosphate manure and mycorrhizal on performance and components of the groundnut. There was a significant interaction between mycorrhizal with phosphor amount and mycorrhizal with vermicompost on all features and inoculation with mycorrhizal had the highest amount relative to other levels and control so that it caused improvement of performance of seed, more than control performance (Seyed *et al*. 2014).

To overcome the problem of chemical fertilizers and to improve the declining productivity, the dependability ratio on chemical fertilizers must be reduced and replaced with biofertilizers.Also there is a very less information available on tillage options as most of the farmers in arid regions preferred for deep tillage to conserve more moisture.Looking to the importance of groundnut in arid region, the need was felt to evaluate the different tillage and nutrient management options. The paucity of information available on the different tillage options in groundnut and their interactions with the integrated nutrient management practices under arid ecosystem of Rajasthan.

MATERIALS AND METHODS

This present study was carried out for two consecutive years in *Kharif* season (2019 and 2020) at Instructional farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University (SKRAU) Bikaner, India (28.01^{o}N latitude, 73.22^{o}E longitude, and an altitude of 234.7 m above mean sea level).The region receives an average annual rainfall is about 274 mm, 70–80% of which occurs during June to September (monsoon season) through south-west monsoon. The soil of the experimental field was loamy sand texture and low in organic carbon (1.1 g kg^{-1}) with a pH 8.5. The soil had available N 120.7 kg ha^{-1}, available P 19.10 kg ha^{-1} and available K 265.8 kg ha^{-1}. The experiment was designed in split-plot with four replications. The total treatment combinations were 18;three tillage practices *viz*., (i) minimum tillage by tractor drawn rotavator (MT), (ii) shallow tillage by tractor drawn disc plough followed by rotavator (ST) and (iii) deep tillage by tractor drawn disc harrow followed by rotavator (DT) in the main plots (120.96 m^2). Six fertilizer interventions namely F0: No NPK fertilization (control), F1: recommended dose of N and K fertilizers (20 and 15 kg ha^{-1}), F2: recommended dose of NPK fertilizer (RDF) @ 20:32:15 kg ha^{-1}, F3: RDF + inoculation with P solubilizing bacteria 2.5 kg (PSB) ha^{-1}, F4: RDF + 2.5 kg PSB ha^{-1} + arbuscular mycorrhizal fungi 2 kg (AMF) ha^{-1} and F5: RDF + 2.5 kg PSB ha^{-1} + 4 kg AMF ha^{-1} as soil application in sub plots of 20.16 m^2 (4.8×4.2 m). The sub plots fertilizer treatments were applied at sowing as per standard procedure.

Groundnut cultivar HNG-69 was seeded at the seed rate of 120 kg ha^{-1} in the third week of June every year at 30 cm row to row and 10 cm plant to plant spacing. Fertilizers were applied as per the technical program. Thereafter a light pre-sowing irrigation (40 mm) was given to maintain the optimum moisture of field for proper germination. All the experimental plots received 10 Mg ha^{-1} of well decomposed sheep manure (0.50-0.52% N, 0.26-0.27% P_2O_5 and 0.56-0.59% K_2O) which was broadcasted uniformly with concomitant tillage operations. Five plants randomly selected from sample rows in each plot were carefully uprooted for estimation of dry matter accumulation at harvest. The sample plants were dried in sun for ten days and then an oven at 70^{O}C to a constant weight. After complete drying, plant samples were weighed by an electronic balance and then averaged to express as dry matter in g plant^{-1}.The pods of five randomly selected plants counted and average number of pods per plant was worked out and recorded as number of pods per plant. A composite sample of 100 gram pods was drawn from the bulk dry pods from each net plot and shelled. The ratio of kernel to pod weight was worked out and expressed in per cent. The nitrogen was estimated by Kjeldahl's method, phosphorus by Vanadomolybdo phosphoric acid, yellow colour method (Jackson, 1973) and potassium by tri-acid digested material by using flame photometer (Jackson,1973). The uptake of nitrogen, phosphorus and potassium was estimated by multiplying yield data with concentration of nutrients. The data obtained for various treatment effects were statistically analysed as per procedure described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means wherever, the "F" test was found significant at 5 per cent level of significance.

RESULTS AND DISCUSSION

Yield and yield attributes. The tillage practices in groundnut significantly influenced the dry matter accumulation at harvest. Although, shallow tillage (ST) practice was at par to deep tillage (DT). Dry matter production with ST and DT might be due to better soil pulverization in comparison to MT. Similar observations was also recorded by Reddy *et al.* (2015) in groundnut. In our study, more branching evidenced the highest number of pods per plant with deep tillage and the similar finding was also reported by Kumar *et al*. (2006). Higher pods per plant with chemical fertilization$\pm$PSB, PSB+AMF might be due to better root development, nodulation and more nutrient availability as evident by increased soil available phosphorus resulting in vigorous plant growth and development which in turn thereby resulted better flowering and pod formation. The similar results were observed by Singh *et al*. (2010, 2015) in lentil and Dutta and Bandyopadhyay (2009) in chickpea. The maximum dry matter accumulation (64.96 and 67.89 g) was recorded with fertilizer treatment F_5 (RDF + 2.5 kg PSB ha ^{1} + 4 kg AMF ha^{-1}), which was at par with F_4 treatment (64.67 and 66.61 g), while the lowest dry matter accumulation (55.45 and 57.62 g) was recorded with F_0 (control) in both the years of 2019 and 2020 at harvest, respectively. The Application of growth regulators significantly increased the number of branches per plant, leaf area, total dry matter accumulation due to increase in cell division and other physiological activities. Due to the increase in leaf area more photosynthates are produced and the total dry matter of the plant was increased. While Azotobacter also helped in the increase of the photosynthesis rate which indirectly showed effect on the dry matter. The present findings correlate the findings of previous workers (Dhoran & Gudadehi, 2012 and Kokare *et al*. 2006).Moreover, P is an important nutrient for all crops particularly legumes and is a key constituent of ATP and plays significant role in energy transformation in plant leads to increased pod yield or may be favourable effect of P on number and weight of nodules and nitrogen activity which in turn might have reflected positively on yield attributes and finally increased the pod yield. These results obtained in the present study corroborates the findings of Kumar *et al*. (2016); Trinhcong (2017).The shelling percentage too exhibited a similar trend as the different organic treatments helped to increase the pod filling and test weight, which in turn favored the improvement in shelling percent. Similar results have been reported by Abraham *et al.* (2008). Highest shelling percentage was recorded with F_5 fertilization (application of RDF + 2.5 kg PSB ha^{-1} + 4 kg AMF ha^{-1}) might be due to the availability of sufficient nutrients in the soil rhizosphere and thereby DMA per plant and its distribution in different parts so as for the effective pod filling. This was in conformity with the finding of Zelate and Padmani (2009). Maximum number of pods per plant (27.0) was recorded with DT and it was at par with ST (25.9) and was significantly higher over minimum tillage (MT) in year 2019. Application of RDF + 2.5 kg PSB ha^{-1} + 4 kg AMF ha^{-1} (27.1 and 30.09) was at par with F_4 treatment (26.3 and 29.49) and the lowest number of pods per plant (20.9 and 21.37) recorded with control in 2019 and 2020.

Data revealed that different tillage practices in groundnut significantly influenced pod yield during both the years. Both DT (3.04 t ha^{-1}) and ST (2.94 t ha^{-1}) practices in groundnut significantly enhanced pod yield over MT (2.70 t ha^{-1}) in 2020. Data further showed that DT gave superiority to the tune of 13.6% over MT in 2019. Different nutrient management practices influenced pod yield of groundnut (Table 1).

Table 1: Effect of tillage and nutrient management practices on growth, yield attributes and yield of groundnut.

Treatments	Dry matter accumulation (g per plant) at harvest		Number of pod per plant		Pod yield (t ha^{-1})		Shelling percentage	
	2019	2020	2019	2020	2019	2020	2019	2020
Tillage practices								
MT	59.66	61.61	21.1	23.50	2.57	2.70	65.12	65.75
ST	61.59	63.65	25.9	28.47	2.77	2.94	70.29	70.41
DT	64.23	67.08	27.0	28.74	2.92	3.04	71.62	74.10
SEm±	0.90	1.03	0.3	0.30	0.06	0.07	1.69	1.81
CD (P=0.05)	3.10	3.58	1.1	1.03	0.20	0.23	5.86	6.25
Nutrient management								
F_0	55.45	57.62	20.9	21.37	2.13	2.40	66.06	65.75
F_1	60.86	63.04	23.2	25.73	2.30	2.66	66.53	68.25
F_2	62.02	63.88	24.7	26.27	2.74	2.84	68.48	70.47
F_3	63.02	65.62	25.8	28.51	2.88	2.97	70.05	71.65
F_4	64.67	66.61	26.3	29.49	3.20	3.21	70.82	72.12
F_5	64.96	67.89	27.1	30.09	3.25	3.28	72.11	72.28
SEm±	0.71	1.05	0.32	0.40	0.07	0.08	1.96	2.06
CD (P=0.05)	2.04	2.98	0.92	1.14	0.20	0.24	5.58	5.87

Where, MT: Minimum tillage, ST: Shallow tillage, DT: Deep tillage, F_0: No NPK fertilization (control), F_1: recommended dose of N and K fertilizers (20 and 15 kg ha^{-1}), F_2: recommended dose of NPK fertilizer (RDF) @ 20:32:15 kg ha^{-1}, F_3: RDF + inoculation with P solubilizing bacteria 2.5 kg (PSB) ha^{-1}, F_4: RDF + 2.5 kg PSB ha^{-1} + arbuscular mycorrhizal fungi 2 kg (AMF) ha^{-1} and F_5: RDF + 2.5 kg PSB ha^{-1} + 4 kg AMF ha^{-1}

Note: NS- Non-significant, DAS- Days after sowing, RDF- Recommended dose of fertilizer, PSB- Phosphate Solubilizing Bacteria, AMF-Arbuscular Mycorrhizal Fungi

The mean maximum pod yield (3.25 and 3.28 t ha^{-1}) was recorded with application of RDF + PSB 2.5 kg ha^{-1} + AMF 4 kg ha^{-1} which was at par with F_4 treatment (3.20 and 3.21 t ha^{-1}) in both the years of investigation. While the lowest pod yield (2.13 and 2.40 t ha^{-1}) was observed with control in 2019 and 2020. Both deep tillage and shallow tillage were recorded higher pod yield compared to MT. Similar results were also obtained by Chaudhary *et al*. (2015); Bala and Nath (2015) in groundnut. Advantageous effects of tillage practices on crop yield and yield attributes of sorghum and pearl millet have also been reported by other workers (Mishra *et al*, 2014; Sinha, 2015). An experiment was conducted in Guilan province and results showed that the effect of irrigation and nitrogen fertilizer on biological yield, pod yield and seed yield was significant at the one percent level in groundnut (Khonok *et al.*, 2015).Use of bio-inoculant (PSB+AMF) with RDF increased yield of pod might be due to the balanced nutrition along with the beneficial effects of bio-inoculants (PSB+AMF) on growth and development, and impact on morphological and photosynthetic components, which ultimately led to profuse root growth and nutrient uptake of the crop. Similar results were also reported by of Bala and Nath, (2015); Rahevar *et al.* (2015); Vala *et al.* (2017) in groundnut. Improved N assimilation and distribution considered as the base of yield formation (Xu *et al*. 2015; de Lima Pereira *et al*. 2016). Patil *et al*. (2015) increased yield of groundnut under tractor drawn tillage treatment was mainly due to deep ploughing which makes soil softer and facilitate the ease penetration of needles (pegs) in to the soil. Deep ploughing might be resulted in better soil moisture conservation which provides water stress free condition for longer period and used soil water more efficiently by the crop as compared with shallow ploughing. Different tillage practices significantly influenced shelling percentage of groundnut. Deep tillage (74.2%) recorded higher shelling percentage over MT (65.7%) in 2020. Various nutrient management practices influenced the shelling percentage of groundnut. Highest shelling percentage (72.1 and 72.2%) was recorded with application of RDF + PSB @ 2.5 kg ha+ AMF @ 4 kg ha^{-1} which was at par with F_4 treatment (70.8 and 72.1%), while the lowest shelling percentage of 66.06 and 65.75 per cent was computed with control in 2019 and 2020.

Nutrient (NPK) uptake. Deep tillage recorded significantly higher N uptake (80.55 and 85.82 kg ha^{-1}) over MT (73.31 and 81.56 kg ha^{-1}), respectively in the year 2019 and 2020. The highest uptake of nitrogen was observed under DT but it did not differ statistically with MT as nitrogen uptake is directly proportional to the accumulation of dry matter in the plant and its nitrogen content. Fertilizer management practices F_4 and F_5 being at par recorded N uptake of 91.99 and 93.25 kg ha^{-1} in 2020. Recommended dose of fertilizer (NPK), F_3 proved statistically superior by NK (F_1) and control (F_0) respectively in respect of N uptake (Table 2).

Table 2: Effect of tillage and nutrient management on nitrogen, phosphorus, potassium uptake in groundnut.

Treatment	Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})	
	2019	2020	2019	2020	2019	2020
Tillage practices						
MT	73.31	81.56	11.49	13.38	72.25	78.98
ST	76.17	83.11	12.13	14.22	77.09	84.72
DT	80.55	85.82	12.43	14.37	78.56	85.05
SEm±	1.80	1.37	0.31	0.27	1.96	1.67
CD (P=0.05)	6.21	4.75	1.06	0.92	6.80	5.78
Nutrient management						
F_0	57.19	71.66	9.58	12.20	59.32	71.02
F_1	65.91	76.34	10.40	12.84	65.02	75.70
F_2	76.76	82.50	11.89	13.78	75.01	81.71
F_3	81.61	85.24	12.57	14.19	79.65	84.35
F_4	88.67	91.99	13.74	15.36	87.74	91.38
F_5	89.92	93.25	13.92	15.57	89.07	93.34
SEm±	2.33	2.13	0.35	0.33	2.34	2.10
CD (P=0.05)	6.64	6.06	1.00	0.94	6.66	5.99

Where, MT: Minimum tillage, ST: Shallow tillage, DT: Deep tillage, F_0: No NPK fertilization (control), F_1: recommended dose of N and K fertilizers (20 and 15 kg ha^{-1}), F_2: recommended dose of NPK fertilizer (RDF) @ 20:32:15 kg ha^{-1}, F_3: RDF + inoculation with P solubilizing bacteria 2.5 kg (PSB) ha^{-1}, F_4: RDF + 2.5 kg PSB ha^{-1} + arbuscular mycorrhizal fungi 2 kg (AMF) ha^{-1} and F_5: RDF + 2.5 kg PSB ha^{-1} + 4 kg AMF ha^{-1}

Note: NS- Non-significant, DAS- Days after sowing, RDF- Recommended dose of fertilizer, PSB- Phosphate Solubilizing Bacteria, AMF-Arbuscular Mycorrhizal Fungi

The highest P uptake (12.43 and 14.37 kg ha^{-1}) was noted under DT practice which showed significant edge over MT (11.49 and 13.38 kg ha^{-1}), however at par with ST (12.13 and 14.22 kg ha^{-1}) in the year of 2019 and 2020. Phosphorus uptake significantly increased by applying nutrient management practices F_1 to F_4 over control (F_0) and maximum values of 13.92 and 15.57 kg ha^{-1} formed in F_5 treatment and minimum P uptake values (9.58 and 12.20 kg ha^{-1}) noted under control during 2019 and 2020. Deep tillage exhibited significantly higher K uptake (78.56 and 85.05 kg ha^{-1}) during 2019 and 2020 over ST. Higher P uptake due to higher number of branches, dry matter production, pod yield, haulm leads to higher p uptake or may be due to solubilization of fixed phosphorus by P-solubilizer due to secretion of organic acids. Similar findings corroborate with the study of Bhatt (2012).Application of RDF + 2.5 kg PSB ha^{-1} + 4 kg AMF ha^{-1} significantly higher potassium uptake (89.07 and 93.34 kg ha^{-1}) and it was at par with F_4 in both the years. The highest uptake of nitrogen was observed under DT and lowest with MT as nitrogen uptake is directly proportional to the accumulation of dry matter in the plant and its nitrogen content. These results are substantiated by the findings of Zamir *et al.* (2012). Nitrogen uptake by groundnut varied by application of different nutrient management practices. Study conducted by Hossain *et al*. (2007) showed that uptake of nitrogen and phosphorus by leaf and stem at different growth stages and also by seed was influenced by applied nitrogen and phosphorus. Phosphorus uptake in groundnut was influenced due to different tillage practices. Uptake of phosphorus was significantly influenced due to application of different nutrient management practices. Phosphorus uptake significantly increased by applying nutrient management practices F_1 to F_4 over control. Enriched sheep yard manure enhanced the greater availability of P which enhanced the cambial activity of root hairs, involved in root cell development and enhanced the root proliferation and root biomass. It helps to allowing the plants to absorb higher quantity of essential nutrients such as N, P and K from rhizosphere soil. This is unfailing with the observations of Saha *et al*. (2015). Increase in available N, P and K due to enriched form of organic manure and chemical fertilizers application may be attributed to the direct addition of these nutrients to the available pool of soil. These results are in concordance with the findings of Fasil Mohmood *et al*. (2017). PSB enhanced the availability of phosphorus to plants, which might have utilized by the crop in greater root development and nodulation that in turn resulted in higher nitrogen fixation in the soil by nodules. Thus, increased availability of nitrogen and phosphorus might have resulted in greater uptake by the plants for proper development and ultimately increased their content in plants. Bouhraoua *et al*. (2015) indicates the great potential of some PSB to improve yield and nutrient uptake of groundnut plants in the presence of native rhizobia and AMF. VAM increased nutrient uptake through reduction of the distance that nutrient must diffuse to plant roots by accelerating the rate of nutrient absorbing surface. Nutrient management practice F_5 recorded the highest K uptake and was at par with F_4 on pooled basis. Potassium is required for translocation of assimilates and involved in maintenance of water status of plant especially the turgor pressure of cells and opening and closing of stomata and increase the availability of metabolic energy for the synthesis of starch and proteins. Potassium improved the quality of groundnut crop (Sanadi *et al*. 2018).

CONCLUSION

Results of the present study revealed the positive effects of deep tillage on pod yield, nutrient uptake in groundnut compared to minimum tillage. Seed inoculation with PSB and AMF in combination with RDF recorded the maximum pod yield over rest of the nutrient management practices. Thus, to maximize the groundnut dry matter, number of pods per plant, pod yield, nutrient uptake, deep tillage along with RDF and bio fertilizers can recommended to the growers in the arid climate of Thar desert.

FUTURE SCOPE

Looking to the fragile ecologies of arid ecosystem, more study is required on the different aspects of crop management to optimise the best management practices (BMPs) for tillage, water and nutrient prescription.

Acknowledgement. More study is required on layering of different management variables like tillage, nutrient, water, energy etc. in groundnut crop so that contribution from the individual variable could be worked out.
Conflict of Interest. None.

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