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Effect of tillage and integrated nutrient management practices on greengram (*Vigna radiata*) crop

RAVINDRA TOMER[1], SANJEEV KUMAR[2], RAHUL KUMAR[1], NEELMANI RATHI[1]* and SUBHRASURAJITA BHOI[3]

Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh 208 002, India

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ABSTRACT

A field experiment was conducted during rainy season of 2015 and 2016 at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur with the objective to evaluate the effects of different tillage and integrated nutrient management (INM) practices on performance of greengram [*Vigna radiata* (L.) Wilczek] under greengram + sesame intercropping system. The experiment was laid out in a split-plot design with four tillage practices, viz. conventional tillage (CT), deep tillage (DT), CT + vegetative mulch and DT + vegetative mulch as main plots, and six INM practices, viz. 20-60-40 N-P_2O_5-K_2O kg/ha, 30-60-40 N-P_2O_5-K_2O kg/ha, 20-60-40 N-P_2O_5-K_2O kg/ha + *Rhizobium* (soil inoculation), 20-60-40 N-P_2O_5-K_2O kg/ha + *Rhizobium* + phosphorus solubilizing bacteria (PSB), 30-60-40 N-P_2O_5-K_2O kg/ha + *Rhizobium* and 30-60-40 N-P_2O_5-K_2O kg/ha + *Rhizobium* + PSB as sub plots with three replications. The DT + vegetative mulch resulted in significantly higher leaf area index (3.10), crop dry matter (10.10 g/plant), seed yield (9.02 q/ha) and net returns (37314.5 INR/ha) with 4.03%, 3.17%, 24.24% and 43% increment over CT, respectively. Among the INM treatments, the 30-60-40 N-P_2O_5-K_2O kg/ha and *Rhizobium* + PSB resulted in highest leaf area index (3.09), crop dry matter (10.09 g/plant), seed yield (9.14 q/ha), net returns (33346.5 INR/ha), and nitrogen (17.67 kg/ha) and phosphorus (9.31 kg/ha) uptake by seed with mean 3.18%, 2.91%, 21.32%, 43.70%, 27.68% and 34.65% increase over sole application of chemical fertilizers.

Keywords: Deep tillage, Nutrient uptake, Phosphorus solubilizing bacteria, *Rhizobium*, Vegetative mulch

Greengram [*Vigna radiata* (L.) Wilczek] is an important *kharif* season pulse crop in India with an annual production of 2.02 million tonnes (ASG 2018). It is an excellent source of high-quality protein (25%), fibre and iron with high digestibility. It is in arid and semi-arid regions of India for seeds, green manure and forage purpose, either as sole or mixed/intercrop. Intercropping is an intensive land-use system that focuses on efficient utilization of inter-row spaces of base crop and available resources by growing a short duration crop. This generates an additional income without adversely affecting the yield of base crop and acts as an insurance against total crop failure. Intercropping with greengram may increase system productivity, maintain soil health, and improve sustainability (Amruta *et al.* 2015). Nutrient and water requirements in an intercropping system are crucial for higher productivity and depend on the companion crops, which should be properly optimised. Appropriate tillage is a cost-effective moisture conservation practice that can conserve soil moisture and improve various soil physical properties, viz. water holding capacity, infiltration, porosity, bulk density, etc. Optimum nutrient supply from appropriate source(s) is another important aspect that not only affects crop performance but the soil quality as well. Inorganic/chemical fertilizer is a costly input and imbalanced or excessive use of it leads to declining soil health, nutrient-use efficiency, making fertilizer use uneconomical with environmental trade-offs (Aulakh and Adhya 2005). However, continuous application of inorganic fertilizers even in balanced form may lead to decline in soil fertility and productivity. Therefore, judicious use of chemical fertilizers in conjunction with organic sources is indispensable for sustaining crop productivity and improving soil health (Kumawat *et al.* 2013). Integrated nutrient management (INM) practices derive maximum benefits from all possible sources of plant nutrients such as organic and inorganic sources in an integrated manner and helps in maintaining optimum soil fertility and crop productivity (Shree *et al.* 2014). Keeping these facts in view, a field experiment was initiated and conducted to evaluate the performance of greengram intercropped with

Present address: [1]ICAR-Indian Agricultural Research Institute, New Delhi; [2]Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh; [3]Odisha University of Agriculture and Technology, Bhubaneswar. *Corresponding author e-mail: neelmanirathi@gmail.com.

sesame under various tillage and INM practices.

MATERIALS AND METHODS

Site characteristics: The field experiment was conducted during *kharif* (rainy season) 2015 and 2016 at Chandra Shekhar Azad University of Agricultural and Technology, Kanpur, Uttar Pradesh. This region has semi-arid climate and alluvial fertile soil. Normal rainfall of the area is about 890 mm per annum with majority of it received during mid-June to end of September (Fig 1).

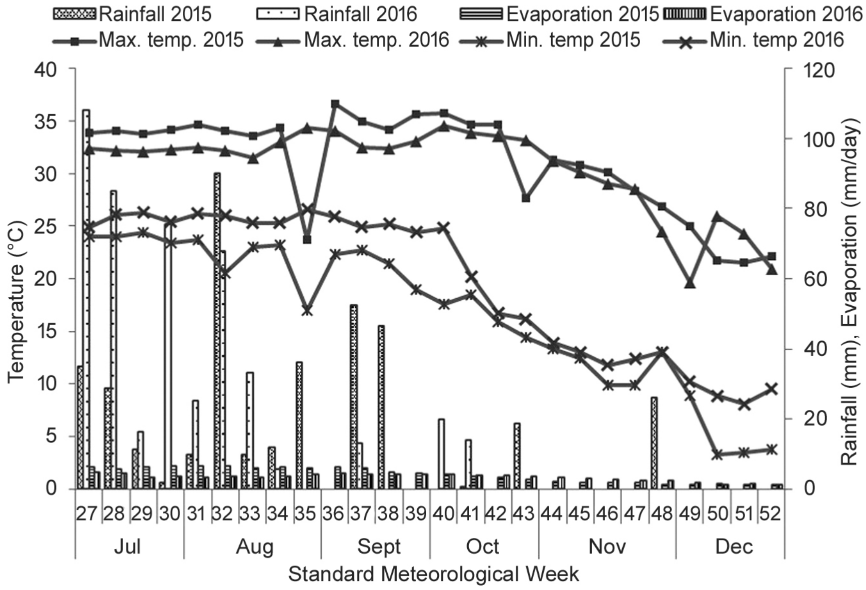

Fig 1 Weather conditions during two years of experimentation.

Treatments details: The experiment was laid out in a split-plot design with four tillage practices, viz. T_1: conventional tillage (CT; 15 cm deep), T_2: deep tillage (DT; 25 cm deep), T_3: CT + vegetative mulch and T_4: DT + vegetative mulch in main plots, and six INM practices, *viz.* F_1: recommended dose of fertilizer (RDF, 20-60-40 N-P_2O_5-K_2O kg/ha), F_2: 30-60-40, F_3: 20-60-40 + *Rhizobium* (soil inoculation), F_4: 20-60-40 + *Rhizobium* + phosphorus solubilizing bacteria (PSB), F_5: 30-60-40 + *Rhizobium* and F_6: 30-60-40 + *Rhizobium* + PSB in sub-plots and three replications. Recommended doses of N, P and K were applied as basal during sowing through urea, diammonium phosphate, and muriate of potash, respectively. The soil was inoculated with bio-fertilizer before sowing of greengram as per the treatments. Greengram cultivar T-44 was sown on 23rd and 25th July and harvested on 27th and 30th October in 2015 and 2016, respectively.

Measurement of leaf area and nutrient uptake: Five random plants were cut at the ground level from second row of each plot and leaves were separated for estimating leaf area using leaf area meter. Leaf area index (LAI) was calculated as;

LAI = Leaf area (cm^2)/Ground area (cm^2)

Then, plant samples were oven-dried at 70 °C until constant dry weight for estimating above-ground biomass and expressed in g/plant. Crop was harvested from net plot area (leaving two border rows on both sides), threshed and seed yield was expressed in q/ha at 12% moisture level. Seed and haulm sample of greengram collected at harvest were oven-dried at 70°C for 48 h and ground in a Wiley mill. Subsequently, nitrogen (N) content in plant samples was determined by modified Kjeldahl method, phosphorus (P) content by colorimetric method using molybdate-vanadate solution, and potassium (K) content by flame photometer (Jackson 1973). Nutrient uptake was calculated separately in seed and haulm as;

Nutrient uptake (kg/ha) = [nutrient content in seed/ haulm (%) × seed (or haulm) yield (kg/ha)]/ 100

Total nutrient uptake (kg/ha) = seed uptake (kg/ha) + haulm uptake (kg/ha)

Consumptive use of water and water-use efficiency: Evapotranspiration from each plot was calculated from the initial and final soil moisture status of an irrigation interval to which number of irrigation intervals was multiplied to get total evapotranspiration. Total seasonal consumptive use of water was then calculated by adding total evapotranspirational demand and effective rainfall of that growing season. The following equations were used to calculate the total consumptive use and water-use efficiency (WUE) of crop.

$$\text{Seasonal consumptive use} = \sum_{i=1}^{n} (bj - ej) + ER$$

bj = total profile moisture content at the beginning of j^{th} interval, ej = total profile moisture content at the end of j^{th} interval, ER = effective rainfall, and n = number of time interval

WUE (kg/ha-mm) = seed yield (kg/ha)/ consumptive use (mm)

Economics and statistical analysis: Minimum support price (MSP) declared by Government of India (MSP) was used to calculate the economics. Net returns were calculated by subtracting total cost of cultivation from gross monetary returns during both the years. Analysis of data was performed using analysis of variance (ANOVA) for split-plot design (Gomez and Gomez 1984). Treatment means were separated by performing least significant difference (LSD) test at $P<0.05$.

RESULTS AND DISCUSSION

Effect on crop growth and seed yield: All the tillage and INM practices influenced crop growth (LAI and above-ground biomass at 60 days after sowing (DAS) and seed yield significantly (Table 1). Significantly higher LAI (3.10) was observed with DT + vegetative mulch with 4.03%, 2.31% and 1.97% increment over CT, DT and CT + vegetative mulch, respectively. Similarly, DT + vegetative mulch

Table 1 Crop growth, seed yield and water-use efficiency of greengram under different tillage and INM practices (mean data of 2-years)

Treatment	Dry matter (g/plant)	Leaf area index	Seed yield (q/ha)	Net returns (×1000 ₹/ha)	Total water use (mm)	WUE (kg/ ha-mm)
Tillage (T)						
T_1: CT	9.79	2.98	7.26	26.1	377.00	2.01
T_2: DT	9.85	3.03	8.32	32.8	362.50	2.40
T_3: CT + vegetative mulch	9.98	3.04	8.46	33.8	357.00	2.48
T_4: DT + vegetative mulch	10.10	3.10	9.02	37.3	346.50	2.73
SEm±	0.09	0.025	0.05	1.29	4.50	0.075
LSD (P< 0.05)	0.31	0.08	0.17	4.0	14.60	0.23
Integrated nutrient management (F)						
F_1: 20-60-40†	9.75	2.98	7.43	22.5	344.45	2.23
F_2: 30-60-40	9.86	3.01	7.64	24.1	350.85	2.25
F_3: 20-60-40 + *Rhizobium*	9.90	3.03	8.20	27.5	353.85	2.40
F_4: 20-60-40 + *Rhizobium* + PSB	9.99	3.07	8.73	30.6	373.8	2.41
F_5: 30-60-40 + *Rhizobium*	9.97	3.05	8.45	28.8	359.45	2.43
F_6: 30-60-40 + *Rhizobium* + PSB	10.09	3.09	9.14	33.4	377.15	2.50
SEm±	0.07	0.02	0.06	1.23	5.00	0.04
LSD (P< 0.05)	0.20	0.05	0.17	3.8	14.29	NS

†Fertilizer dose in $N:P_2O_5:K_2O$; CT: conventional tillage; DT: deep tillage; PSB: phosphorus solubilizing bacteria; WUE: water-use efficiency; NS: non-significant

resulted 3.17%, 2.54% and 1.20% higher biomass over CT, DT and CT + vegetative mulch, respectively. Besides, DT + vegetative mulch led to highest seed yield (9.02 q/ha) which was 24.24%, 8.41 and 6.62% higher than CT, DT and CT + vegetative mulch, respectively (Table 1). The DT was at par with CT + vegetative mulch in terms of LAI, above-ground biomass and seed yield of greengram. Among INM practices, supplementing 30-60-40 (N-P_2O_5-K_2O kg/ ha) with *Rhizobium* and PSB resulted in highest LAI (3.09) and above-ground crop biomass (10.09 g/plant) with 2.66-3.69% and 2.33-3.48% increment over RDF only (F_1 and F_2), and it was comparable with 20-60-40 + *Rhizobium* + PSB. Likewise, 30-60-40 + *Rhizobium* + PSB treatment led to the highest seed yield of greengram (9.14 q/ha) (Table 1). Similar beneficial effects of integrating chemical fertilizer with microbial inoculants (synthetic fertilizer + N-fixer + P-solubilizer and/or plant growth-promoting rhizobacteria) were also reported by Samant and Patra (2016) in *rabi* greengram, Jakhar *et al*. (2018) in pearlmillet and Verma and Yadav (2019) in chickpea. Combination of DT + vegetative mulch and 30-60-40 + *Rhizobium* + PSB (T_4× F_6) resulted in highest seed yield (9.80 q/ha) which was 29.80-45.40% higher over tillage without mulching and RDF. The DT + vegetative mulch in conjunction with 20-60-40 + *Rhizobium* + PSB (T_4× F_4) was the next best combination. Beneficial effects of tillage (CT/DT) and vegetative mulching were attributed to better soil moisture conservation (8.4% over CT), weed control, and additional nutrient supply, leading to better crop growthv and development and seed yield. Furthermore, integration of microbial organisms (*Rhizobium* and PSB) with fertilizers led to fixation of higher atmospheric N and more solubilisation of fixed P in soil that resulted in better crop growth with higher LAI and dry matter accumulation. Dry matter accumulation and LAI are indicators of photosynthetic efficiency. Higher leaf area put forth by better crop growth led to greater photosynthesis and higher dry matter accumulation, resulting in significant yield improvement. Moreover, 20-60-40 + *Rhizobium* + PSB (F_4) was comparable with 30-60-40+*Rhizobium*+PSB (F_6) with regard to crop growth. This indicates that integration of bio-inoculants (*Rhizobium* and PSB) with chemical fertilizers (20-60-40) could achieve similar growth in greengram as that in sole 30-60-40, thereby reduction in chemical fertilizer use.

Water use and water-use efficiency: Total water use and WUE varied significantly across the tillage and nutrient management practices (Table 1). The DT + vegetative mulch conserved greater amount of soil moisture. Total consumptive use of water in DT + vegetative mulch was 30.5 mm less (8.4% less) that resulted in 35.82% more WUE (2.73 kg/ha-mm) as compared to CT (Table 1). The DT was as effective as CT + vegetative mulch in conserving soil moisture and improving WUE. Lower total water requirement under DT + vegetative mulch treatment might be owing to soil moisture conservation and reduced soil evaporation. The DT facilitates more water infiltration and holds moisture in deeper soil layers. Soil mulching blocks direct sunlight to soil, moderates soil temperature, and thus restricts evaporation rate of water from soil. Mulching also reduces weed growth and its corresponding heavy

Table 2 Nutrients (N, P and K) content and uptake in seed and haulm of greengram as influenced by tillage and INM practices (mean data of 2-years)

Treatment	Nutrients content (%)						Nutrients uptake (kg/ha)					
	N		P		K		N		P		K	
	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm
Tillage (T)												
T_1: CT	1.81	0.98	0.91	0.55	0.71	1.54	13.01	12.01	6.59	6.74	5.12	18.92
T_2: DT	1.83	0.99	0.96	0.58	0.73	1.63	15.04	13.89	7.95	8.12	6.08	22.87
T_3: CT + vegetative mulch	1.90	1.03	0.98	0.59	0.79	1.80	15.98	14.72	8.29	8.45	6.67	25.81
T_4: DT + vegetative mulch	2.00	1.09	1.00	0.60	0.82	1.89	17.95	16.46	9.03	9.17	7.35	28.72
SEm±	0.008	0.01	0.01	0.01	0.01	0.03	0.17	0.16	0.09	0.09	0.09	0.40
LSD (P<0.05)	0.027	0.034	0.033	0.035	0.034	0.104	0.59	0.55	0.31	0.30	0.31	1.38
Integrated nutrient management (F)												
F_1: 20-60-40†	1.84	1.00	0.91	0.55	0.71	1.56	13.56	11.37	6.72	6.25	5.25	17.70
F_2: 30-60-40	1.85	1.01	0.93	0.56	0.73	1.61	14.13	12.44	7.12	6.95	5.57	19.91
F_3: 20-60-40 + *Rhizobium*	1.87	1.02	0.95	0.57	0.76	1.69	15.25	14.12	7.77	7.96	6.18	23.55
F_4: 20-60-40 + *Rhizobium* + PSB	1.91	1.04	1.00	0.60	0.79	1.80	16.53	16.00	8.65	9.25	6.85	27.76
F_5: 30-60-40 + *Rhizobium*	1.88	1.03	0.97	0.59	0.77	1.74	15.84	14.35	8.21	8.22	6.49	24.40
F_6: 30-60-40 + *Rhizobium* + PSB	1.94	1.06	1.02	0.61	0.82	1.89	17.67	17.34	9.31	10.09	7.48	31.19
SEm±	0.01	0.01	0.01	0.01	0.01	0.03	0.28	0.29	0.12	0.18	0.11	0.69
LSD (P< 0.05)	0.029	0.028	0.030	0.028	0.029	0.086	0.80	0.82	0.32	0.50	0.31	1.93

†Fertilizer dose in $N:P_2O_5:K_2O$; CT: conventional tillage; DT: deep tillage; PSB: phosphorus solubilizing bacteria

transpiration. Thus, lower water use and higher seed yield resulted in better WUE in this treatment. Similar effects of tillage practices on water use and WUE were reported by Tetrawal *et al*. (2013) in Indian mustard and Singh *et al*. (2019) in yellow sarson. Among nutrient management practices, 30-60-40 + *Rhizobium* + PSB resulted in significantly higher total crop water requirement than that of other treatments (26.3-32.7 mm or 7.50-9.49% higher than F_1 and F_2), and was comparable with 20-60-40 + *Rhizobium* + PSB (Table 1). Higher water use in this treatment was attributed to rapid crop growth and concomitant higher crop evapotranspiration rate. However, WUE did not vary significantly across various nutrient management practices (Table 1).

Nutrients (N, P and K) content and uptake: Tillage and nutrient management practices significantly influenced the N, P and K content and uptake in seed and haulm of greengram (Table 2). The DT + vegetative mulch resulted in significantly higher N, P and K content in seed (2.0%, 1.0% and 0.82%, respectively) and haulm (1.09%, 0.60% and 1.89%, respectively) of greengram than those in other treatments (Table 2). The N, P and K content of seed with DT + vegetative mulch treatment was 10.50%, 9.89% and 15.49% higher, respectively, as compared to CT. Among INM practices, 30-60-40 + *Rhizobium* + PSB led to significantly higher N, P and K content in seed (1.94%, 1.02% and 0.82%, respectively) and haulm (1.06%, 0.61%, and 1.89%, respectively) of greengram than those in other treatments (Table 2). The N, P and K content of seed in 30-60-40 + *Rhizobium* + PSB were 4.86-5.43%, 9.68-12.09% and 12.33-15.49% higher as compared to RDF only (F_1 and F_2). The DT + vegetative mulch resulted in significantly higher N, P and K uptake by seed (17.95 kg/ha, 9.03 kg/ha and 7.35 kg/ha, respectively) and haulm (16.46 kg/ha, 9.17 kg/ha and 28.72 kg/ha, respectively) than those of other treatments (Table 2). The DT + vegetative mulch resulted in 37.97%, 37.03% and 43.55% higher N, P and K uptake by seed over CT, respectively. Among INM practices, 30-60-40 + *Rhizobium* + PSB resulted in significantly higher N, P and K uptake by seed (17.67 kg/ha, 9.31 kg/ha and 7.48 kg/ha, respectively) and haulm (17.34 kg/ha, 10.09 kg/ha and 31.19 kg/ha, respectively) than those in other treatments (Table 2). This led to 25.05-30.31%, 30.76-38.54% and 34.29-42.48% higher N, P and K uptake by seed over RDF only (F_1 and F_2). Higher nutrients uptake in DT + vegetative mulch might be due to enhanced shoot and root growth through better moisture availability and additional nutrient supply to plant roots upon decomposition of mulching materials. Integrated use of chemical fertilizer and beneficial microbes exerted beneficial effects in fixation, solubility and release of nutrients in inorganic forms in soil, and ultimately their uptake by plant roots.

Economics: The highest net returns were obtained with DT + vegetative mulch that led to 43%, 13.7% and 10.4% higher net returns over CT, DT and CT + vegetative mulch, respectively. Higher seed yield with this treatment led to higher net returns (Table 1). Among nutrient management practices, higher seed yield with the application of chemical fertilizer (30:60:40) + *Rhizobium* + PSB (INM) resulted in maximum net returns (Table 1) with 39-48% increase over inorganic fertilizers only (F_1 and F_2). Application of 20:60:40 + *Rhizobium* + PSB was comparable with 30-60-40 + *Rhizobium* + PSB and led to 28-36% higher net returns over chemical fertilizers only (F_1 and F_2).

Comparative analysis of various tillage and nutrient management practices: Tillage practices: Deep tillage (25 cm) reduced total consumptive use of greengram by 3.85% (14.5 mm) and led to 19.40% higher WUE over CT. On contrary, vegetative mulching could save 5.31% (20 mm) water consumption in CT and 4.42% (16 mm) water use in DT over without mulching. Similarly, mulching resulted in 23.38% higher (in CT-based) and 13.75% higher (in DT-based) WUE over without mulching. Total water uses and WUE in DT was comparable to CT + vegetative mulching; however, the former led to 1.54% higher water use and 3.23% lower WUE than those with the later.

Nutrient management practices (seed yield): Only RDF (F_1 and F_2) fetched 12.69% less seed yield than INM practices (F_3, F_4, F_3 and F_6). Soil inoculation of *Rhizobium* and chemical fertilizer inflicted 10.50% yield advantages over chemical fertilizer only. Similarly, integration of *Rhizobium* + PSB with chemical fertilizer led to 7.33% yield gains over chemical fertilizer + *Rhizobium*. Likewise, soil inoculation of *Rhizobium* + PSB along with chemical fertilizer led to 18.6% higher seed yield as compared to that with chemical fertilizer only.

The results of two year experimentation revealed that vegetative mulching could save considerable amount of soil moisture leading to higher water-use efficiency, productivity and profitability along with lower total consumptive use of water by greengram. The conjunctive use of recommended dose of chemical fertilizer and *Rhizobium* + phosphorus solubilizing bacteria resulted in highest productivity, nutrient uptake and net returns of greengram under greengram + sesame intercropping system in comparison to sole application of chemical fertilizers.

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