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Effect of tillage, residue and weed management on soil properties, and crop productivity in greengram (*Vigna radiata* L.) under conservation agriculture

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Abstract
Effect of tillage, crop residue and weed management on soil properties, and crop productivity in greengram (Vigna radiata L.) was evaluated under conservation agriculture in Central India, Jabalpur M.P. Soil bulk density at 0–15 cm layer was reduced both by tillage and residue, while zero-tillage with residue treatment significantly increased the soil organic carbon content. Yields of greengram was significantly higher under ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G) in maize–mustard-greengram cropping systems, more so with residue addition. When no residue was added, conventional tillage reduced soil fertility and productivity than the zero-tillage. Although zero-tillage resulted in better C content and N availability in soil, and reduced the economic inputs, cultivation of summer greengram appeared to be profitable under conservation tillage system with residue and weed management.

Keywords: tillage, residue, management, greengram, agriculture

Introduction

In the Central India, fields remain fallow for 70–80 days during summer after the harvest of winter crops. Short-duration crops like summer greengram (Vigna radiata L.) can be grown during this period with assured irrigation. This practice has occupied an area of about 1.0 M ha as it provides additional income, improves soil fertility and ensures efficient land utilization (Sharma, Prasad, Singh & Singh, 2000; Sharma &Sharma, 2004). It is the most important pulse crop after pigeonpea and chickpea. It is a short duration crop, tolerant to photoperiod and thermal variations, and thus has scope for expansion in time and area during spring and summer seasons. Intensive tillage-based agriculture practices without recycling of organic resources deteriorate the soil quality (Lal *et al*., 1994), which then reduce, the overall productivity of greengram. Conservation agriculture (CA) is a crop management system based on the three principles of minimum soil disturbance, crop residue retention, and crop rotation (FAO, 2010). It has the potential to improve resource-use efficiency, crop productivity and soil health, while maintaining the environment (Kassam *et al*., 2009). It is worth mention here that conservation agriculture is practiced presently on about 125 million ha globally (FAO, 2012). In addition to reduction in the cost of cultivation (Malik *et al*., 2005) and getting stable yields (Abrol & Sangar, 2006). Although optimum sowing time for summer greengram in Central India is the 1st week of April. Conventional tillage practices, involving cultivator followed by a rotavator for seed-bed preparation, further delay the sowing about 7–10 days. Zero tillage, on the other hand can advance the sowing time, as the crop can be sown without any field preparation through a single tractor operationus using specially designed seed-cum-fertilizer drill or raised bed planter. Among the various factors of low productivity of crops, competition by weeds is the major one (Bhan and Kewat, 2003). If weeds are not controlled during critical periods of crop-weed competition, there is identical reduction in the yields of greengram, to the tune of (77-85%) (Nandan *et al*. 2011), depending upon the types and intensity of weeds. Though surface residue retention in zero-tillage suppresses weed emergence to a certain extent, residues also restrict manual or mechanical weed control (Mhlanga *et al*., 2016). Hand weeding is a traditional and effective method of weed control, but untimely and continuous rains as well as unavailability of labour during peak period of demand, are the main limitations of manual weeding. Therefore, it is necessary to find out the alternative methods for reducing the weed load during early growth period of crops to get economical yields.

In this study, the performance of greengram, as a component in maize-based rotations, was evaluated in terms of yield, under conventional and zero tillage with or without residues. Some major soil properties were also studied including soil C and available N content, to identify the best tillage- crop rotation combinations.

Materials and methods

Experimental site and location

The field experiment was conducted at the Research Farm, of ICAR-Directorate of Weed Research, Adhartal, Jabalpur (M.P.). Jabalpur is situated at 23^0 09' North latitude and 79^0 58' East longitudes with an altitude of 412 m above the mean sea level. The field selected for experimentation was laser-levelled having uniform topography and was fairly infested with location-specific weeds representing this area. All physical facilities *viz*., labours, agrochemicals, equipments and irrigation water etc. were adequately available as per needs on the research farm. The mean annual rainfall of Jabalpur is 1350 mm, mostly received between mid-June to end-September with a little and occasional rains in remaining parts of the year. The mean monthly temperature goes down to 4 ^{0}C during winter, while the maximum temperature reaches up to 45 ^{0}C during the summer. Generally, relative humidity remains very low during summer (15-30%), moderate during winter (60-75%), and attains higher values (80-95%) during rainy season. To evaluate the physico-chemical properties of soil of the experimental field, sixteen soil samples were drawn randomly from the depth of 0-15 cm from different spots with the help of screw type soil augar. After this, all soil samples were thoroughly mixed together to make a composite sample. After proper drying, the composite sample was powdered finally with the help of pistle and morter and then subjected to analysis in the laboratory. It is obvious from the data that the soil of the experimental field was clayey in texture, neutral in reaction (pH 7.2), medium in organic C (0.68%) and analyzing medium in available nitrogen (215.5 kg ha^{-1}), medium in available phosphorus (12.4 kg ha^{-1}) and high in available potassium (385 kg ha^{-1}).

Treatment detail

The trial had five main treatments and three sub-treatments in a split-plot design with additional one control treatment with three replications. The study was conducted on gross plot size of 18.0 m ×11.4 m with a net plot size of 5.0 m× 2.1 m during each year in the same plot.

The main plot or tillage and residue management treatments *viz.* T_1 conventional tillage- conventional tillage [CT (M)–CT (Msr)], T_2 conventional tillage-zero tillage- zero tillage [CT (M)–ZT (Msr)–ZT (G)], T_3 zero tillage + greengram residue-zero tillage-zero tillage + mustard residue [ZT+GR (M)–ZT (Msr)–ZT+MsR (G)], T_4 zero tillage-zero tillage + maize residue-zero tillage + mustard residue, [ZT (M)–ZT+MR (Msr)–ZT+MsR (G)], T_5 zero tillage + greengram residue-zero tillage + maize residue-zero tillage + mustard residue [ZT+GR (M) –ZT+MR(Msr)–ZT+MsR (G)]; and three sub plot treatments or weed management practices; *viz.* W_1 Pendimethalin (PE) 750 g/ha *fb* imazethapyr (PoE) 1000 g/ha, W_2 Pendimethalin (PE) 750 g/ha *fb* quizalofop (PoE) 1000 g/ha, W_3 Pendimethalin 750 g/ha (PE) *fb* HW at 25 DAS, W_4 unweeded control under zero tillage was alone maintained as additional.

Crop establishment of greengram

In some part of Central India, mungbean is grown in summer season also. The crop is sown in March to early April and harvested in May and June. Only short duration varieties maturing in 60-70 days can be grown with adequate irrigation facilities in this season. Timely sowing of summer mungbean is more important. The delay in sowing affects the yield adversely. The late-sown crop may be caught by the early monsoon rains at harvesting time which may create a problem for harvesting and threshing and ultimately the yield is reduced. If fields are already lying vacant this crop can be sown at any time after mid February. However, if the fields have been cultivated under *rabi* crops, mungbean should be planted immediately after harvesting the preceding crop. In case if the fields are released very late, sowing of mungbean with 'zero tillage' can also be done. Under this practice, mungbean can be sown in the stubbles of wheat just after the latter has been harvested and given irrigation. This practice reduced the cost of cultivation and also saves lot of time which is most important during this season (Komal *et al.* 2015).

Crop residue

Sun-dried residues of mustard were applied @ 5 t ha^{-1} to the greengram crops. Crop residues were spread as mulch before sowing in the respective plot.

Grain and stover yields

The yield attributes such as number of pods $plant^{-1}$**,** length of pod and number of seeds pod^{-1} of greengram crops was calculated from 10 random plants from each treatment. The crop from the net plot area of 5.0 x 2.1 m was harvested manually, dried in the sun for 2-3 days, and threshed. The weight of seed and stover was worked out.

Results

Yield attributes and yield

The data on number of pods $plant^{-1}$, seed yield and stover yield are presented in Table 1 and 2 which reflect that tillage and weed management did exert significant impact.

Among tillage and residue management, maximum number of pods $plant^{-1}$, seed yield and stover yield was recorded with zero-tilled greengram with mustard residue [ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G)] and was on par with ZT (M)-ZT+MR (Msr)-ZT+MsR (G) at 25 DAS during both years and on mean basis also. Among weed management, number of pods $plant^{-1}$, seed yield and stover yield was higher with pendimethalin *fb* HW and was on par with pendimethalin *fb* imazethapyr during 2017. The average of three weed management practices in terms of all this parameters compared to control was significant. The interaction between tillage and weed management practices was not significant. The yield attributes like number of seeds pod^{-1}, pod length and 100-grain weight did not vary due to tillage and weed management practices since both characters are governed by genetic factors. Greengram grown in zero-till condition significantly influenced the yield attribute like no of pods $plant^{-1}$ in both the years. Higher values of yield attributes of greengram under zero-tilled greengram with mustard residue [ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G)] may be due to the more favourable growth and better utilization of resources. Among weed management practices, maximum values of yield attributes were found under pendimethalin *fb* HW and followed by pendimethalin *fb* imazethapyr which caused significant improvement in crop growth and reduction in weed competition, which ultimately led to better formation of yield attributes during both years. This corroborates the results of Meena *et al*. (2015)

Table 1: Effect of tillage, residue and weed management on yield attributes and yield of greengram

Treatment	Yield attributes								
	Pods plant^{-1}			Seed yield (t ha^{-1})			Stover yield (t ha^{-1})		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
Tillage and residue management (T)									
CT (M)-CT (Msr)	-	-	-	-	-	-	-	-	-
CT (M)-ZT (Msr)-ZT (G)	35.92	28.50	32.21	1.10	0.91	1.01	3.10	2.71	2.91
ZT+GR (M)-ZT (Msr)-ZT+MsR (G)	36.77	28.65	32.71	1.14	0.94	1.04	3.14	2.90	3.02
ZT (M)-ZT+MR (Msr)-ZT+MsR (G)	38.08	30.55	34.32	1.19	1.00	1.10	3.26	3.01	3.13
ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G)	39.58	32.03	35.80	1.25	1.08	1.17	3.79	3.10	3.45
SEm ±	0.50	0.78	0.38	0.03	0.02	0.01	0.12	0.01	0.06
LSD (p=0.05)	1.63	2.53	1.23	0.10	0.05	0.05	0.40	0.04	0.21
Weed management (W)									
Pendimethalin *fb* imazethapyr	37.36	27.84	32.60	1.15	0.97	1.06	3.29	2.90	3.09
Pendimethalin *fb* quizalofop	33.61	27.77	30.69	1.08	0.89	0.99	3.07	2.74	2.91
Pendimethalin *fb* HW	40.79	31.31	36.05	1.24	1.05	1.14	3.47	3.03	3.25
SEm ±	0.38	0.82	0.51	0.01	0.01	0.01	0.10	0.01	0.05
LSD (p=0.05)	1.12	2.41	1.48	0.04	0.04	0.03	0.29	0.03	0.15
Control vs others									
Control	28.79	22.75	25.77	0.79	0.68	0.73	2.21	2.14	2.17
Other	37.25	28.97	33.11	1.16	0.97	1.06	3.28	2.89	3.08
SEd ±	0.88	1.90	1.17	0.03	0.03	0.02	0.23	0.03	0.12
LSD (p=0.05)	1.83	3.94	2.42	0.06	0.07	0.04	0.47	0.05	0.24
Interaction (T X W)									
SEm ±	0.85	1.84	1.13	0.03	0.03	0.02	0.22	0.03	0.11
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

CT = Conventional tillage, ZT = Zero tillage, M = Maize, Msr = Mustard, G = Greengram, GR = Greengram residue, MR = Maize residue, MsR= Mustard residue

It was observed that the greengram seed and stover yield (Table 1) was significantly higher in zero-tilled greengram with mustard residue retention [ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G)] than CT (M)-CT (Msr) over the years, indicating residual effect of tillage and residue management practice. This may be ascribed due to better nodulation and yield attributes under zero tillage alongwith residue retention. The final yield of greengram plant is a function of yield components like number of pods plant^{-1}, number of seeds pod^{-1}, pod length and 100-grain weight**.** Higher seed and stover yield under pendimethalin *fb* HW and followed by pendimethalin *fb* imazethapyr was due to the weed managed at critical period and better early crop growth which resulted in higher production of photosynthates and greater translocation of food materials to the reproductive parts particularly number of seeds pod^{-1} and ultimately high yield. Lower weed population and higher weed control efficiency also resulted in higher seed and stover yield. The lower seed yield under weedy check may be due to the high weed interference. Similar result was found by Komal *et al.* (2015). The yield of greengram during 2016 was lower than 2015 it may because of fact that fluctuated weather condition and favourable for insect attack in crop.

Physico-chemical properties of soil

Data presented in Table 2 and 3 showed that, tillage practices during the course of experimentation have significantly influenced the BD, organic C, N, P and K. However, weed management practices did not cause significant influence on above parameters. Among tillage and residue, BD, organic C, N, P and K was maximum under zero-tillage with residue retention of preceding crops [ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G)] which was on par with ZT (M)-ZT+MR (Msr)-ZT+MsR (G) after completion of two crop cycles. Interaction between tillage and weed management was not significant.

Table 2: Physico-chemical properties of soil of experimental field before sowing of maize (initial) and after harvesting of greengram (final) during first crop cycle

Treatment	Physico-chemical properties of soil													
	Bulk density (g cm^{-3})		pH		EC (ds m^{-1})		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})		Organic carbon (%)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Tillage and residue management (T)														
T_1	1.43	1.45	7.19	7.25	0.32	0.32	212.40	212.82	12.08	12.16	360.22	361.21	0.66	0.67
T_2	1.43	1.47	7.14	7.11	0.32	0.32	212.98	213.49	12.14	12.21	362.03	363.01	0.67	0.67
T_3	1.43	1.48	7.19	7.08	0.33	0.32	213.09	213.40	12.15	12.27	364.83	365.06	0.67	0.68
T_4	1.42	1.49	7.23	7.14	0.33	0.32	213.72	214.08	12.35	12.65	365.30	366.24	0.68	0.68
T_5	1.40	1.50	7.21	7.19	0.32	0.32	214.58	214.63	12.23	12.69	365.85	367.54	0.68	0.69
SEm±	0.01	0.00	0.03	0.03	0.00	0.00	0.27	0.43	0.11	0.10	1.50	1.22	0.00	0.00
LSD (0.05)	NS	0.01	NS	NS	NS	NS	0.87	1.40	0.36	0.31	4.88	3.98	0.00	0.01
Weed management (W)														
W_1	1.41	1.48	7.25	7.17	0.33	0.32	213.34	213.65	12.19	12.34	361.36	362.26	0.67	0.68
W_2	1.42	1.47	7.16	7.17	0.33	0.32	213.20	213.35	12.25	12.45	367.10	366.31	0.67	0.67
W_3	1.43	1.49	7.17	7.13	0.32	0.32	213.52	214.05	12.13	12.40	362.49	365.26	0.67	0.68
SEm±	0.01	0.00	0.02	0.01	0.00	0.00	0.14	0.22	0.11	0.06	1.08	0.73	0.00	0.00
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Control vs others														
Control	1.45	1.47	7.09	7.16	0.32	0.32	211.86	212.14	11.96	11.81	359.10	360.12	0.66	0.66
Other	1.42	1.48	7.19	7.15	0.32	0.32	213.35	213.68	12.19	12.40	363.65	364.61	0.67	0.68
SEd ±	0.01	0.01	0.05	0.03	0.01	0.01	0.32	0.51	0.25	0.14	2.49	1.68	0.00	0.00
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (T X W)														
SEm ±	0.01	0.01	0.05	0.03	0.01	0.00	0.31	0.49	0.24	0.14	2.42	1.63	0.00	0.00
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Physico-chemical properties of soil of experimental field before sowing of maize (initial) and after harvesting of greengram (final) during second crop cycle

Treatment	Physico-chemical properties of soil													
	Bulk density (g cm^{-3})		**pH**		**EC (dS m^{-1})**		**Available N (kg ha^{-1})**		**Available P (kg ha^{-1})**		**Available K (kg ha^{-1})**		**Organic carbon (%)**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
Tillage and residue management (T)														
T_1	1.45	1.47	7.25	7.09	0.32	0.33	212.82	213.06	12.16	12.23	361.21	362.01	0.67	0.68
T_2	1.47	1.51	7.11	7.10	0.32	0.33	213.49	213.99	12.21	12.50	363.01	363.13	0.67	0.70
T_3	1.48	1.51	7.08	7.10	0.32	0.33	213.40	214.70	12.27	12.41	365.06	366.07	0.68	0.70
T_4	1.49	1.51	7.14	7.11	0.32	0.33	214.08	214.33	12.65	12.77	366.24	366.79	0.68	0.70
T_5	1.50	1.50	7.19	7.12	0.32	0.32	214.63	214.76	12.69	12.80	367.54	367.80	0.69	0.71
SEm±	0.00	0.01	0.03	0.01	0.00	0.00	0.43	0.36	0.10	0.06	1.22	0.95	0.00	0.00
LSD (0.05)	0.01	0.02	NS	NS	NS	NS	1.40	1.16	0.31	0.19	3.98	3.09	0.01	0.01
Weed management														
W_1	1.48	1.50	7.17	7.11	0.32	0.33	213.65	214.36	12.34	12.49	362.26	363.36	0.68	0.69
W_2	1.47	1.50	7.17	7.09	0.32	0.33	213.35	213.92	12.45	12.49	366.31	366.79	0.67	0.70
W_3	1.49	1.50	7.13	7.11	0.32	0.32	214.05	214.22	12.40	12.65	365.26	365.33	0.68	0.70
SEm±	0.00	0.00	0.01	0.01	0.00	0.00	0.22	0.21	0.06	0.06	0.73	0.63	0.00	0.00
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control vs others														
Control	1.47	1.47	7.16	7.15	0.32	0.33	212.14	213.91	11.81	11.97	360.12	361.23	0.66	0.68
Other	1.48	1.50	7.15	7.10	0.32	0.33	213.68	214.17	12.40	12.54	364.61	365.16	0.68	0.70
SEd ±	0.01	0.01	0.03	0.01	0.01	0.01	0.51	0.50	0.14	0.14	1.68	1.46	0.00	0.00
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (T X W)														
SEm ±	0.01	0.01	0.03	0.01	0.00	0.00	0.49	0.48	0.14	0.13	1.63	1.41	0.00	0.00
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Conventional tillage recorded slightly lower bulk density in surface soil (0-15 cm) than the ZT. But the differences among the all treatments in respect to bulk density in surface soil were non significant. In general, BD of the surface soil layer (0-15 cm) was less in CT (M)-CT (Msr) treatments than ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G) as compared to sub surface soil layer (15-30 cm).

In this study, zero-tillage resulted in a net increase C content over conventional tillage. Ploughing disturbs the soil and promotes oxidation of organic C in soils. Studies reported 30–60% of C depletion due to cultivation in the sub tropical regions of India (e.g. Swarup, Maana & Singh, 2000; Lal, 2000). A net increase in SOC content was observed with crop residues under both zero and conventional tillage. This was obviously associated with a large amount of crop residues and root biomass C in residue-added plots, which significantly improved the yield of crops (Mandal *et al.*, 2008).

The physical properties (bulk density, water holding capacity and moisture content) and chemical properties (pH, electrical conductivity, organic C, available N, P_2O_5 and K_2O) content of soil did not vary after harvesting of crop due to herbicide application as compared to the initial. However, BD and organic C were minutely influenced due to tillage practices. Similar result found by (Ghosh *et al.* 2012). The compaction of soil is generally quantified by bulk density (BD) which affect the crop growth and development. In general, surface soil layer (0-15 cm) was having lower BD than sub-surface soil layer (15-30 cm). In ZT, there was slightly higher BD than CT. It is due to less porosity in surface soil as no ploughing is done. Whereas, in subsurface soil, ZT recorded considerably lower BD than CT because of less machinery (machine weight, tire width, inflation pressure), number of passing, as well as optimum soil moisture content (Botta *et al.* 2005). Residue management also reduced the BD due to more macro-pores development and better soil aggregation. Soil moisture content in surface soil is always higher in ZT with residue retention than CT. De Vita *et al.* (2007) reported that it is due to less water evaporation, radiation insulation effect of residue and shedding effect on surface soil. The stability and proportions of aggregate size distribution play a pivotal role for maintaining good soil physical health. Residues also influence the nutrients by proving the better energy source for micro-organisms in soil. These microbes ultimately improve the soil aggregation (Six *et al.* 1999). Zero tillage with residue, regulated the soil temperature in crops by maintaining higher temperature in cool season and lower temperature in warmer season. It might be due to changes in specific heat capacity, thermal conductivity, thermal diffusivity and albedo of soil. The soil physical parameters were not influenced by herbicidal treatments.

Conclusions

Inclusion of summer greengram in a maize–mustard cropping system could be a viable option for obtaining higher crop productivity, improving soil fertility, and increasing economic efficiency. Cultivation of summer greengram was most profitable under conservation tillage with crop residue addition. Cropping systems under zero-tillage are more environment-friendly (contributing better soil aggregation, C accumulation and N availability) and sustainable (energy saving). Zero-tilled greengram with mustard residue retention [ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G)] with pendimethalin *fb* imazethapyr in greengram resulted in more productivity and income as compared to weedy check. Practicing combination of zero-tillage, residue recycling and integrated weed management over a period of two cropping cycles resulted in significant improvement in soil physical (BD, moisture status), chemical (N, P and K status, organic carbon) and biological (microbes and enzymatic activity) health. A combination of zero-tilled crops with the retention of residues of mustard crops [ZT+GR (M)-ZT+MR (Msr)-ZT+MsR (G)] with integrated weed management may be recommended for higher productivity, profitability and soil health in greengram crop in maize-mustard-greengram cropping system. These findings are important from the standpoint of reducing cost of cultivation, ensuring higher productivity and sustainability in the vertisols of central India.

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