Indian Journal of Agronomy **60** (2): 205–211 (June 2015)

Research Paper

System productivity, profitability, nutrient uptake and soil health under tillage, nutrient and weed management in rainfed chickpea (*Cicer arietinum*)–fodder sorghum (S*orghum bicolour*) cropping system

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Received : July 2014; Revised accepted : April 2015

ABSTRACT

A field experiment was conducted during winter (*rabi*) 2010–11 to rainy season (*kharif*) 2013 at Jhansi, Uttar Pradesh to study the effect of tillage practices, nutrient management and weed control in chickpea (*Cicer arietinum* L.)–fodder sorghum [S*orghum bicolor* (L.) Moench] cropping system under rainfed conditions. Pooled data of 3 years study revealed that reduced tillage recorded significantly higher weed count, i.e. 6.56 broad leaf weeds and 5.56 grassy weeds/m^2 during the winter (*rabi*) and higher grassy weeds count (10.52 weeds/m^2) and weed dry-matter (297.6 kg/ha) during the rainy season (*kharif*) than conventional tillage. Reduced tillage and conventional tillage recorded statistically similar chickpea equivalent yield (CEY) of chickpea and system productivity and protein yield of system. However, reduced tillage recorded significantly higher chickpea equivalent yield of fodder sorghum (1.11 t/ha) and nutrient uptake (119.2 kg N and 5.50 kg P/ha). Application of 50% of recommended dose of nutrients (RDN) through chemical fertilizers + 5 t FYM/ha in chickpea–fodder sorghum cropping system recorded significantly higher chickpea-equivalent yield of chickpea (1.08 t/ha), fodder sorghum (1.17 t/ha) and system (2.26 t/ha), protein yield (914 kg/ha) and nutrient uptake (163.2 kg N, 8.9 kg P, 168.0 kg K and 12.5 kg S/ha) of the cropping system. Twice manual weeding recorded 25.6 and 14.9% lower weed count and weed dry matter yield during the winter (*rabi*) season and 25.1 and 17.8% lower weed count and weed dry-matter yield during the rainy (*kharif*) season, respectively, than application of recommended herbicides. Although twice manual weeding gave 11.2% higher chickpea-equivalent yield than herbicidal weed management but due to higher cost of cultivation (₹44,913/ha) under manual weeding, application of recommended herbicide in chickpea–fodder sorghum system was profitable because it gave higher net returns (₹18,952/ha) and benefit: cost ratio (0.50). Soil-fertility status, viz. organic carbon and available NPKS, also improved over their initial status with integrated use of tillage, nutrient and weed management in chickpea–fodder sorghum cropping system.

Key words: Chickpea, Fodder sorghum, System Productivity, Tillage, Weed

Under rainfed condition of semi-arid tropics of India, sorghum–chickpea is the predominant cropping system which contributes substantially to meet the food, feed and fodder requirement of the country. However, the productivity of system is low due to suboptimal input management like imbalanced application of nutrients including secondary and micro nutrients and non-adoption of weed-management practices. Under rainfed situation, moisture stress has been identified as one of most important factors limiting chickpea yield (Angadi *et al.,* 2008) during the post-rainy season. Soil-moisture content can be regulated by different tillage-management practices. Optimum tillage is an important factor determining the productivity and profitability of crops in rainfed systems owing to its impact on residual soil moisture availability. Introducing conservation tillage (zero tillage/reduced tillage) in crops like chickpea may improve productivity as a result of timely sowing, and may also reduce fuel, animal or human energy required for land preparation.

Nutrient management is another important agronomic practice which greatly affects productivity and profitability of the cropping system, but in recent past due to increased cropping intensity, imbalance in nutrient application and increased reliance on inorganic fertilizers alone, the productivity of soils has gone down. Role of the organics in improving soil fertility and sustainability of the cropping system is well documented. It ensures regulated supply of

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nutrients by releasing them slowly, resulting in increased crop yield and nutrient-use efficiency (Sharma, 2002), long-term sustainability of soil fertility by improving level of soil organic carbon, availability of nutrients and soil microbial properties (Melero *et al*., 2007). Therefore, it is necessary to replace the some portion of inorganic fertilizers with organic sources of nutrients to sustain the fertility and productivity of soils for longer period.

Weeds are naturally efficient and aggressive in utilizing the resources–nutrients and moisture and can compete with the crops to cause economic loss. Chickpea being poor competitor to weeds, especially during initial growth period suffers 18–90% yield loss depending on the nature and intensity of weed flora and management practices (Yaduraju and Mishra, 2002). Mishra (1997) reported 15–40% loss in sorghum yield due to weeds. Weed infestation in early growing season reduces yields significantly. Soil tillage is one of the most important factors determining the abundance of weeds within given cropping systems. Wet soil conditions during the rainy season in heavy soils do not permit either mechanical weeding or hand–weeding to create weed–free conditions. Hence under such a situation, use of herbicide is the only option to reduce the weed menace during early growth stage.

To improve the overall productivity and stability of chickpea-based food-fodder cropping system proper management of critical inputs, viz. tillage, nutrients and weed management, is essential. Since information on food-fodder-based system is particularly in rainfed condition of central India is meagre, current study was conducted to find out suitable tillage, nutrient and weed-management strategy in chickpea–fodder sorghum cropping system for higher yield with improved soil health under rainfed condition of semi-arid region.

MATERIALS AND METHODS

A fixed-plot field experiment was conducted at the Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi (25°27' N and 78°35' E and 271 m above mean sea-level) during winter season (*rabi*) 2010–11 to rainy season (*kharif*) 2013. The eco-region lies under semi-arid tropical (SAT) climate. Experiment was laid out in factorial randomized block design with 4 replications, comprising 2 tillage practices, viz. conventional tillage (2 harrowing followed by planking in the last pass) and reduced tillage (1 harrowing followed by planking), 2 nutrient-management options, viz. 100% recommended dose of nutrients (RDN) through inorganic fertilizers (20 kg N, 40 kg P_2O_5, 20 kg K_2O, 20 kg S and 20 kg Zn/ha in chickpea and 60 kg N, 30 kg P_2O_5 and 30 kg K_2O/ha in fodder sorghum) and 50% of RDN of respective crops (chickpea/fodder sorghum) through inorganic fertilizers + 5 t FYM/ha and 2 weed-control approaches, viz. application of recommended herbicide (pendimethalin in chickpea and atrazine in sorghum) and twice manual weeding. 'Avarodhi' variety of chickpea and 'PC 6' variety of sorghum were sown under rainfed condition. The total rainfall received during the growing period was 1,106, 789 and 1,485 mm in 2010–11, 2011–12 and 2012–13 respectively.

Composite top soil samples representing the whole field were taken before sowing, and plot-wise samples were collected after completion of 3 years cropping cycle for analysis of physical and chemical properties. The soil samples were analyzed for *p*H (in 1:2.5 soil water suspension using glass electrode), organic carbon and electrical conductivity. The bulk density of 0–15 cm and 15–30 cm soil depth was determined using core sampler. Available N, P and K were determined by $KMnO_4$ oxidizable N, Olsen method and extraction with 1N ammonium acetate (NH_4OAC solution at pH 7.0), respectively (Singh *et al*., 1999). The experimental soil was clay loam with *p*H 7.05, electrical conductivity 0.125 dS/m and bulk density 1.27 Mg/m^3 in 0–15 cm and 1.39 Mg/m^3 in 15–30 cm soil depth. The initial status of soil organic carbon, available nitrogen, phosphorus, potassium, sulphur and zinc were 0.621%, 249.5 kg/ha, 20.6 kg/ha, 174.4 kg/ha, 31.0 kg/ha and 0.51 mg/kg soil respectively.

The crop yield was recorded as per standard procedures. After harvesting treatment-wise seed, straw and plant samples were collected for nutrient analysis and nutrient uptake studies. Observations on weed were recorded just before harvesting. To compute the productivity of system chickpea-equivalent yield (CEY) of fodder sorghum or chickpea straw was calculated by using the following formula.

CEY = [Yield of fodder sorghum or chickpea straw (t/ha) × Price of fodder or straw (₹/t)]/Price of chickpea grain (₹/t).

System productivity was worked out by adding chickpea-equivalent yield of chickpea crop including grain and straw and fodder sorghum for respective years. The soil-moisture content was recorded from 0–15 cm and 15–30 cm soil depth at the time of sowing and harvesting of chickpea. A three-factor analysis of variance (ANOVA) technique was carried out to test the significance of treatments. Critical difference (CD at P=0.05) was used for pair-wise comparison of means.

RESULTS AND DISCUSSION

Weed dynamics

Different management practices had significant effect on weed count and weed-dry matter during the growth period of chickpea and fodder sorghum (Table 1). The

major weed flora in the chickpea–fodder sorghum cropping system comprised *Chenopodium album* L., *Anagallis arvensis* L., *Medicago denticulata, Vicia sativa* L. and *Melilotus indica* L. (52.4%) among broad leaved; *Avena fatua* L., *Phalaris minor* Retz. and *Cynodon dactylon* L. (45.8%) among grassy weeds during growing period of chickpea. In fodder sorghum, *Cynodon dactylon, Echinochloa colonum* (L.) Link, *Digitaria sanguinalis* (L.) Scop and *Dinebra retroflexa* (Vahl) Panz were dominant (58.9%) among grassy weeds; *Commelina bengalensis* L., *Amaranthus viridis* L., *Ageratum conyzoides* L. and *Phyllanthus niruri* L. (43.1%) among broad leaved weeds and *Cyperus* spp (4.5%) among sedges. Reduced tillage recorded significantly higher weed count, i.e. 6.56 broad-leaf weeds and 5.56 grassy weeds/m^2 during growing period of chickpea and higher grassy weeds count (10.5 weeds/m^2) and weed-dry matter (297.6 kg/ha) during growing period of fodder sorghum than conventional tillage. Dry-matter yield of weed during growing period of chickpea and weed count of broad-leaf and sedges in sorghum remained unaffected due to tillage practices. Rathore *et al*. (1998) reported less weed biomass in conventional tillage than in no tillage chickpea. Similarly, higher weed density and dry weight in zero-tillage compared to conventional tillage was also reported by Arif *et al*. (2007), Mishra and Singh (2011) and Monsefi *et al*. (2013). Nutrient-management also affected the weed population, significantly higher grassy weeds and broad-leaf weeds were recorded with the application of 50% of RDN through inorganic fertilizers + 5 t FYM/ha than application of 100% of RDN through inorganic fertilizers in *rabi* seasons. However, data on dry-matter yield of weed during the winter (*rabi*) season and weed count and dry-matter yield of weed during the rainy season remained unaffected due to nutrient-management approaches. Weed count and weed dry-matter yield at the crop harvesting stage reduced significantly with twice manual weeding than the application of recommended herbicides in both the seasons. Twice manual weeding recorded 25.6 and 14.9% lower weed count and weed dry-matter yield respectively, during the winter season and 25.1 and 17.8% lower weed count and weed dry-matter yield respectively, during the rainy season than application of recommended herbicides.

Soil moisture

The soil-moisture content in the both the tillage practices were at par at sowing and harvesting stages.

Table 1. Influence of tillage on soil-moisture content, weed dynamics and weed dry weight in chickpea–fodder sorghum cropping system under rainfed condition (pooled data of 3 years)

Treatment	Soil moisture content (%) during *rabi* season				Weed studies in chickpea at 75 DAS			Weed studies in fodder sorghum at 75 DAS			
	At sowing		At harvesting		Weed count/m^2		Weed-dry matter (kg/ha)	Weed count/m^2			Weed-dry matter (kg/ha)
	0–15 cm	15–30 cm	0–15 cm	15–30 cm	Grassy weeds	Broad-leaf weeds		Grassy weeds	Broad-leaf weeds	Sedge weeds	
Tillage management											
Conventional tillage	11.87	14.45	7.23	11.04	4.92	5.84	155.6	9.80	6.52	0.80	277.0
Reduced tillage	11.89	14.53	7.42	11.25	5.56	6.56	165.1	10.52	6.16	0.75	297.6
SEm±	0.11	0.09	0.08	0.12	0.10	0.12	4.4	0.20	0.20	0.02	4.10
CD (P=0.05)	NS	NS	NS	NS	0.31	0.35	NS	0.60	NS	NS	12.06
Nutrient management											
100% RDN through chemical fertilizers	11.79	14.41	7.14	10.99	5.00	5.96	157.3	10.24	6.2	0.77	281.4
50% RDN through chemical fertilizers + 5 t FYM/ha	11.97	14.58	7.51	11.30	5.48	6.44	163.4	10.08	6.48	0.78	293.3
SEm±	0.11	0.09	0.08	0.12	0.10	0.12	4.4	0.20	0.204	0.02	4.10
CD (P=0.05)	NS	NS	0.24	NS	0.31	0.35	NS	NS	NS	NS	NS
Weed management											
Application of recommended herbicide	11.81	14.46	7.21	10.93	6.24	6.88	173.2	10.76	8.00	0.98	310.8
Twice manual weeding	11.95	14.53	7.44	11.36	4.28	5.48	147.4	9.56	4.64	0.58	263.9
SEm±	0.11	0.09	0.08	0.12	0.10	0.12	4.4	0.20	0.204	0.02	4.10
CD (P=0.05)	NS	NS	NS	0.36	0.31	0.35	12.95	0.60	0.608	0.07	12.06

But, nutrient and weed management had significant effect on the soil-moisture content in 0–15 cm and 15–30 cm soil depth at harvesting of chickpea (Table 1). Application of 50% of RDN through inorganic fertilizers + 5 t FYM/ha recorded 7.5% soil moisture in 0–15 cm soil depth and twice manual weeding recorded 11.4% soil moisture in 15–30 cm soil depth which were significantly higher than their respective counterparts. Kumar *et al*. (1984) also reported that the application of FYM caused a progressive increase in the volume of water retained at a given suction; together with a small increase in available water. Adequate supply of moisture is known to influence positively the growth and productivity of crop directly as well as indirectly by increasing the availability and utilization of nutrients.

System productivity

Pooled data of 3 years field study on tillage management in chickpea–fodder sorghum cropping system showed that chickpea-equivalent yield (CEY) of chickpea (grain and straw yield) crop and system was statistically at par between conventional tillage and reduced tillage, but CEY of fodder sorghum was significantly higher (1.11 t/ha) reduced tillage than conventional tillage (Table 2). The reduced tillage and conventional tillage in chickpea recorded 1.04 and 1.07 t/ha CEY respectively. However, system productivity in terms of CEY was higher under reduced tillage (2.16 t/ha) than conventional tillage. Our findings are contradictory to the earlier reports of Barzegar *et al.* (2003) and Tripathi *et al.* (2004) who reported that chickpea yield was significantly affected by various tillage systems and direct drilling gave lower yield.

Application of 50% of RDN through inorganic fertilizers + 5 t FYM/ha had significant effect on productivity of different components of chickpea–fodder sorghum cropping system in terms of CEY as compared to the treatment receiving 100% recommended dose of nutrients through inorganic fertilizers (Table 2). Application 50% of RDN through inorganic fertilizers + 5 t FYM/ha gave 5.03, 16.5 and 10.7% higher CEY by chickpea, fodder sorghum and system, respectively, than 100% RDN through chemical fertilizers. Similarly, higher yield of chickpea was also observed owing to the residual effect of application of 25% N through FYM + 25% N through vermi-compost + 50% N through RDF applied to preceding forage sorghum in the rainy season followed by 100% RDF application respectively (Nawale *et al*., 2009). The Gawai and Pawar (2007) reported significant residual effect of FYM (5 t/ha) application on chickpea yields in sorghum–chickpea cropping system.

Twice manual weeding in chickpea and fodder sorghum gave significantly higher CEY than application of recommended herbicide (Table 2). Twice manual weeding recorded 14.9, 10.4 and 12.6% higher CEY by chickpea,

Table 2. Influence of tillage, nutrient and weed management in chickpea–fodder sorghum cropping system on system productivity on the basis of chickpea equivalent yield (CEY), economics and protein yield from under rainfed condition (pooled data of 3 years)

Treatment	Chickpea equivalent yield (t/ha)			Economics of system				Protein yield of system (kg/ha)
	Chickpea (Grain + straw)	Fodder sorghum	System productivity	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio	
Tillage management								
Conventional tillage	1.07	1.07	2.14	41,555	57,770	16,215	0.36	851
Reduced tillage	1.04	1.11	2.16	39,005	58,359	19,354	0.46	881
SEm±	0.02	0.1	0.02	-	-	-	-	11
CD (P=0.05)	NS	0.04	NS	-	-	-	-	NS
Nutrient management								
100% RDN through chemical fertilizers	1.03	1.01	2.04	39,509	55,231	15,722	0.37	818
50% RDN through chemical fertilizers + 5 t FYM/ha	1.08	1.17	2.26	41,051	60,897	19,846	0.45	914
SEm±	0.02	0.01	0.02	-	-	-	-	11
CD (P=0.05)	0.05	0.04	0.05	-	-	-	-	32
Weed management								
Application of recommended herbicide	1.00	1.03	2.02	35,647	54,598	18,952	0.50	818
Twice manual weeding	1.13	1.14	2.27	44,913	61,533	16,619	0.34	914
SEm±	0.02	0.01	0.02	-	-	-	-	11
CD (P=0.05)	0.05	0.04	0.05	-	-	-	-	32

RDN, Recommended dose of nutrient; FYM, farmyard manure

Selling price of chickpea grain was ₹21, 28 and 30/kg; chickpea stover ₹1.0, 1.5 and 2.0/kg; and green fodder was ₹750, 1,000 and 1,250/t during 2010–11, 2011–12 and 2012–13, respectively.

fodder sorghum and system respectively, than application of recommended herbicides in chickpea–fodder sorghum cropping system. The higher yield of twice manual weeding plots was owing to the lower weed population as reflected through dry weight of weeds (Table 1) and better crop canopy development, which resulted in more efficient utilization of solar energy and nutrients by crop. Conservation agricultural practices increase the system productivity of different cropping systems (Ramesh *et al.*, 2013).

Protein yield

Pooled data on system protein yield showed that integrated use of tillage, nutrient and weed management significantly influenced the protein yield of the chickpea–fodder sorghum cropping system compared to their respective control (Table 2). Reduced tillage resulted in significantly higher protein yield than conventional tillage. Pooled data showed that reduced tillage recorded protein yield of 881 kg/ha and was significantly higher (3.5%) over protein yield received from conventional tillage. Application of 50% of RDN through fertilizers + 5 t FYM/ha resulted in 914 kg/ha protein yield which was significantly higher than 100% RDN through fertilizers by 11.7% from chickpea–fodder sorghum system. Twice manual weeding had also recorded significantly higher protein yield than application of recommended dose of herbicides. Higher protein yield under reduced tillage, 50% RDN through chemical fertilizers + 5 t FYM/ha and twice manual weeding was owing to higher grain and straw yield by chickpea and dry matter yield by fodder sorghum under these treatments.

Nutrient uptake

Nitrogen, phosphorus, potassium and sulphur uptake by chickpea, potassium and sulphur uptake by fodder sorghum was at par under both tillage practices, i.e. reduced and conventional tillage, whereas fodder sorghum recorded significantly higher nitrogen and phosphorus uptake under reduced tillage than conventional tillage (Table 3). The nutrient uptake by the cropping systems was also at par under reduced and conventional tillage management practices, however, reduced tillage removed 5.7, 0.28, 5.9 and 0.16 kg more N, P, K and S/ha respectively. Application of 50% of RDN through chemical fertilizers + 5 t FYM/ha gave significantly higher nitrogen, phosphorus, potassium and sulphur uptake by chickpea, fodder sorghum and whole system than application of 100% of RDN through chemical fertilizers. Application of 50% of RDN through chemical fertilizers + 5 t FYM/ha in chickpea–fodder sorghum cropping system removed 17.4, 0.94, 18.4 and 1.13 kg more N, P, K and S/ha respectively, than application of 100% of RDN through chemical fertilizers.

Table 3. Influence of tillage on nutrient uptake in chickpea–fodder sorghum cropping system under rainfed condition (pooled data of 3 years).

Treatment	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)			Sulphur uptake (kg/ha)		
	Chickpea	Sorghum	System	Chickpea	Sorghum	System	Chickpea	Sorghum	System	Chickpea	Sorghum	System
Tillage management												
Conventional tillage	39.2	112.5	151.6	3.10	5.14	8.27	29.2	126.5	155.8	6.55	5.25	11.80
Reduced tillage	38.1	119.2	157.3	3.05	5.50	8.55	28.4	133.3	161.7	6.40	5.56	11.96
SEm±	0.61	2.13	2.06	0.05	0.10	0.10	0.46	2.53	2.41	0.11	0.10	0.13
CD (P=0.05)	NS	6.27	NS	NS	0.32	NS	NS	NS	NS	NS	NS	NS
Nutrient management												
100% RDN through chemical fertilizers	37.7	108.1	145.8	2.97	4.97	7.94	28.1	121.4	149.6	6.28	5.04	11.32
50% RDN through chemical fertilizers + 5 t FYM/ha	39.6	123.6	163.2	3.18	5.70	8.88	29.5	138.5	168.0	6.67	5.77	12.45
SEm±	0.61	2.13	2.06	0.05	0.10	0.10	0.46	2.53	2.41	0.11	0.10	0.13
CD (P=0.05)	1.80	6.27	6.06	0.15	0.32	0.30	NS	7.44	7.11	0.32	0.31	0.39
Weed management												
Application of recommended herbicide	35.9	110.2	146.1	2.84	5.08	7.92	26.8	123.9	150.8	6.00	5.20	11.17
Twice manual weeding	41.4	121.5	162.9	3.30	5.60	8.90	30.8	135.9	166.7	6.95	5.64	12.60
SEm±	0.61	2.13	2.06	0.05	0.10	0.10	0.46	2.53	2.41	0.11	0.10	0.13
CD (P=0.05)	1.80	6.27	6.06	0.15	0.32	0.30	1.36	7.44	7.11	0.32	0.31	0.39

RDN, Recommended dose of nutrients; FYM, farmyard manure

Similarly, twice manual weeding also recorded significantly higher nitrogen, phosphorus, potassium and sulphur uptake by chickpea, fodder sorghum and whole system than application of recommended herbicide. Uptake of N, P, K and S was 16.8, 0.98, 15.9 and 1.43 kg/ha more under twice manual weeding in chickpea–fodder sorghum cropping system than its respective control. Observed difference in nutrient uptake due to different treatments was mainly due to difference in biomass production.

Soil fertility

Tillage, nutrient and weed-management practices in chickpea–fodder sorghum cropping system, exhibited significant variation in different soil properties (Table 4). All the parameters of soil fertility observed after three years showed improvement over their initial value. Nutrient management affected significantly all the physico-chemical properties of soil, viz. bulk density at 0–15 cm soil depth, electrical conductivity, organic carbon, available N, available P, available K, available S and available Zn status. Application of 50% of RDN through chemical fertilizers + 5 t FYM/ha recorded higher organic carbon (0.67%), available N, available P, available K, available S and available Zn and lower bulk density of 0–15 cm soil layer (1.30 Mg/m^3) and electrical conductivity than application of 100% of RDN through chemical fertilizers. The improvement could be attributed to addition of greater root biomass and organic matter through FYM. Availability of soil nutrients (available N, P, K and S) is always influenced due to addition or depletion of such nutrients in the soil, but favourable response was more pronounced with integrated nutrient-management than chemical fertilizers alone. Thus addition of organic sources with chemical fertilizers improved the physico-chemical properties of soil compared to initial fertility status. Gawai and Pawar (2007) also reported the beneficial effect of integrated nutrient management on available nitrogen, phosphorus and potassium content of soil under sorghum–chickpea cropping system. In case of bulk density, reduced tillage showed significant decrease in bulk density at 15–30 cm soil depth. Reduced tillage also showed increase in electrical conductivity. The available nitrogen content was significantly higher in manually weeded plots in comparison to chemical control. Ramesh *et al.* (2013) also reported that the application of conservation agricultural practices has beneficial effect on soil fertility, especially soil organic carbon (0.41%) in castor–sorghum cropping system compared to conventional practices.

Relative economics

Mean data on cost of cultivation, gross returns, net returns and benefit: cost ratio of 3 years study on tillage, nutrient and weed management in chickpea–fodder sorghum cropping system were compared among different treatments (Table 2). Due to higher economic yield, gross return was higher in reduced tillage, application of 50% of RDN through chemical fertilizers + 5 t FYM/ha and twice manual weeding than their respective controls (Table 2).

Table 4. Influence of tillage on soil health after 3 years study in chickpea–fodder sorghum cropping system under rainfed condition.

Treatment	Bulk density (Mg/m^3) 0–15 cm	Bulk density (Mg/m^3) 15–30 cm	*p*H	Electrical conductivity (dS/m)	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available S (kg/ha)	Available ZN (mg/kg soil)
Tillage management										
Conventional tillage	1.31	1.43	6.70	0.121	0.64	257.6	20.7	171.7	33.2	0.535
Reduced tillage	1.34	1.38	6.73	0.166	0.66	259.1	19.9	174.1	34.3	0.537
SEm±	0.01	0.01	0.02	0.002	0.02	2.68	0.3	2.0	0.4	0.002
CD (P=0.05)	NS	0.03	NS	0.006	NS	NS	NS	NS	NS	NS
Nutrient management										
100% RDN through chemical fertilizers	1.35	1.41	6.71	0.148	0.63	241.8	19.5	168.4	33.1	0.528
50% RDN through chemical fertilizers + 5 t FYM /ha	1.30	1.40	6.72	0.141	0.68	274.9	21.1	177.4	34.4	0.544
SEm±	0.01	0.01	0.02	0.002	0.02	2.68	0.3	2.0	0.4	0.002
CD (P=0.05)	0.04	NS	NS	0.006	0.05	7.89	1.0	6.0	1.2	0.008
Weed management										
Application of recommended herbicide	1.34	1.41	6.71	0.139	0.65	250.4	20.1	171.9	33.5	0.538
Twice manual weeding	1.31	1.40	6.72	0.149	0.65	266.3	20.5	173.9	34.0	0.535
SEm±	0.01	0.01	0.02	0.002	0.02	2.68	0.3	2.0	0.4	0.002
CD (P=0.05)	NS	NS	NS	0.006	NS	7.89	NS	NS	NS	NS
Initial value	1.27	1.39	7.05	0.125	0.62	249.5	20.6	174.4	31.0	0.51

RDN, Recommended dose of nutrients; FYM, farmyard manure

But due to higher cost of cultivation i.e. ₹41,555, 41,051 and 44,913/ha under conventional tillage, application of 50% of RDN through chemical fertilizers + 5 t FYM/ha and twice manual weeding, respectively (Table 2), reduced tillage, application of 50% of RDN through chemical fertilizers + 5 t FYM/ha and herbicidal weed management recorded ₹19,354/ha and 0.46, ₹19,846/ha and 0.45 and ₹18,952/ha and 0.50 net returns and benefit: cost ratio respectively, which were higher than their respective controls. These results are close conformity with the findings of Gawai and Pawar (2006).

It was concluded that reducing the tillage intensity from 2 harrowing (conventional tillage) to 1 harrowing (reduced tillage) in each season was effective in reducing the cost of cultivation without affecting the yield. Similarly, application of 50% of RDN through chemical fertilizers + 5 t FYM/ha and herbicidal weed management in chickpea–fodder sorghum cropping system was also economically beneficial under semi-arid tropical climate of central India. Hence reduced tillage with integrated nutrient management and chemical weed control may be recommended for increased productivity, higher economic return and improved soil health.

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